ANKARA YILDIRIM BEYAZIT UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES



THE DIFFERENCES BETWEEN SHORT-TERM AND LONG-TERM TEST METHODS IN ASR EXPERIMENTS

M.Sc. Thesis by

Saifuldeen Sufyan Ahmed AL-INIZI

Department of Civil Engineering

July, 2021

ANKARA

THE DIFFERENCES BETWEEN SHORT-TERM AND LONG-TERM TEST METHODS IN ASR EXPERIMENTS

A Thesis Submitted to

The Graduate School of Natural and Applied Sciences of Ankara Yildirim Bayezit University

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Civil Engineering

by

Saifuldeen Sufyan Ahmed AL-INIZI

July, 2021

ANKARA

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"THE DIFFERENCES BETWEEN SHORT-TERM AND LONG-TERM TEST METHODS IN ASR EXPERIMENTS"** completed by **SAIFULDEEN SUFYAN AHMED AL-INIZI** under supervision of **PROF. DR. LUTFULLAH TURANLI** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Prof. Dr. Lutfullah TURANLI

(Supervisor)

Assoc. Prof. Dr. Serdar GÖKTEPE

(Jury Member)

Prof. Dr. Afşin SARITAŞ

(Jury Member)

Prof. Dr. Sadettin ORHAN

(Director)

Graduate School of Natural and Applied Sciences

ETHICAL DECLARATION

I hereby declare that, in this thesis which has been prepared in accordance with the Thesis Writing Manual of Graduate School of Natural and Applied Sciences,

- All data, information, and documents are obtained in the framework of academic and ethical rules,
- All information, documents, and assessments are presented in accordance with scientific ethics and morals,
- All the materials that have been utilized are fully cited and referenced,
- No change has been made on the utilized materials,
- All the works presented are original,

And in any contrary case of the above statements, I accept to renounce all my legal rights.

Date: 16.07.2021 **Signature: …….…….....**

Name & Surname: Saifuldeen Sufyan Ahmed AL-INIZI

ACKNOWLEDGMENTS

- First and foremost, I thank God Almighty for his grace and blessings.

- I am very grateful to my parents (my mother and father) for encouraging me with their prayers, sympathy, and tenderness, who supported me financially and spiritually.

- I am very grateful to my beloved (Iqbal) my dear wife who was with me in every moment and supported me until I completed my studies.

- I thank my thesis advisor, Prof. Dr. Lutfullah TURANLI, for his tremendous support, extensive knowledge, and valuable recommendations that were the highlight of this study, and he was directed to me throughout my research and during the writing of this thesis.

- I would like to thank Asst. Prof. Dr. Nahla HILAL, who provided me with assistance and guidance in scientific research.

- I would like to Dr. Alkan HAFÇI, who helped me and provided me with some of the references that I adopted in my thesis.

- I thank the close study friends for all their support and assistance throughout the study period.

- I would like to thank everyone in my family who wished me success in my studies, and I also thank all of my friends who have been in contact with me throughout the previous period.

- Finally, I want to thank everyone; I will do my best to live up to your expectations.

2021, July **Saifuldeen Sufyan Ahmed AL-INIZI**

THE DIFFERENCES BETWEEN SHORT-TERM AND LONG-TERM TEST METHODS IN ASR EXPERIMENTS

ABSTRACT

The main objective of this thesis is to identify the common test methods used for the determination of alkali-silica reaction (ASR) in concrete, and furthermore provide testing requirements and limitations of these test methods through the rigorous inspection of past research studies conducted on this field. ASR was first detected by Stanton in the 1940s, and his research work formed the basis of most of the research studies undertaken in this field. Since then, researchers have been trying to develop faster and reliable test methods in detecting the ASR in concrete.

In this thesis, details of 16 short-term and long-term test methods used for the determination of ASR in concrete are provided. Description of the test methods is outlined with respect to the selection of the materials, testing apparatus, and requirements. Furthermore, a literature survey on the use of these test methods is presented in order to outline the advantages and disadvantages of each method, as well as their limitations. The conclusion of this thesis provides suggestions on the choice of the most suitable test method to detect alkali-silica reaction in concrete under varying conditions.

Keywords: Alkali-silica reaction, short-term tests, long-term tests, expansion limit, ASTM standards.

ASR DENEYİMLERİNDE KISA VE UZUN SÜRELİ TEST YÖNTEMLERİ ARASINDAKİ FARKLAR

ÖZ

Bu çalışmanın amacı, betonda alkali-silika reaksiyonunun (ASR) tespitinde yaygın olarak kullanılan test yöntemlerini belirlemek ve bu test yöntemlerinin yürütülme şartlarını detaylı olarak anlatarak kısıtlamalarını tespit etmektir. Bu incelemeyi yapabilmek için betonda ASR'nin tespitine yönelik yürütülen geçmiş çalışmalardan faydalanılmıştır. ASR'nin ilk tespit edilmesi 1940 yıllarında Stanton tarafından yürütülen çalışmalara dayanmaktadır ve bu önemli tespitten sonra pek çok çalışmada farklı test yöntemleri önerilmiş ve ASR'nin daha hızlı ve doğru bir şekilde belirlenebilmesi için araştırmalar yürütülmüştür.

Bu tez çalışmasında, pratikte ve araştırma seviyesinde kullanılan 16 farklı test yöntemi dikkate alınmıştır. Bu test yöntemlerinden bir kısmı kısa süreli bir kısmı da uzun süreli test yöntemleri olarak ikiye ayrılmıştır. Bu test yöntemlerinin yürütülmesi için gerekli olan malzemeler, deney düzeneği ve yürütme şartları detaylı bir şekilde açıklanmıştır. Bu test yöntemlerinin avantaj ve dezavantajlarının belirlenmesi için bu alanda yürütülmüş bilimsel çalışmalardan faydalanılmış ve bu test yöntemlerinin kısıtlamaları tespit edilmiştir. Tez çalışmasının sonunda, farklı şartlar altında betonda ASR'nin tespiti için en uygun test yönteminin belirlenmesine yönelik tavsiyeler verilmiştir.

Anahtar Kelimeler: Alkali-silika reaksiyonu, kısa süreli testler, uzun süreli testler, genleşme sınırı, ASTM standartları.

CONTENTS

M.Sc THESIS EXAMINATION RESULT FORM iii
ETHICAL DECLERATION iv
ACKNOWLEDGMENTS v
ABSTRACT vi
ÖZ vii
NOMENCLATURE x
LIST OF TABLES xi
LIST OF FIGURES xii

CHAPTER 1 INTRODUCTION 1
1.1 General 1
1.2 Alkali-Silica Reaction Mechanism 3
1.3 Alkali-Silica Expansion Control Factors 4
1.4 Objectives of the Study 5
1.5 Organization of the Thesis 6
CHAPTER 2 TEST METHODS FOR ALKALI SILICA REACTION 7
CHAPTER 3 LITERATURE REVIEW 50
3.1 Predictability of Aggregates Improved by ASR Study 50
3.2 Comparative Study of Field and Lab Results on Concrete on ASR 51
3.3 A Comparative Study Between RTA T363 and ASTM C1260 Methods to Detect Reactive Aggregates 52
3.4 Checking of Recycled Concrete Using Accelerated ASR Test 54
3.5 Predicting ASR Using ASTM C1293, C1260, and Their Updates 55
3.6 Suggested Autoclaving in Glass Aggregate Bound Composites for ASR Screening 56
3.7 Test of ASR Using a Modified ASTM C1260 57

3.8 ASR in Mortars Produced from Aggregates of Various Levels of Crystallinity 59
3.9 A Critical Evaluation for ASR Performance in Concrete 60
3.10 Assessing ASR of Aggregate Using an Accelerated Autoclave Test 61
3.11 New Test for AAR in Iceland 62
3.12 ASR Kinetic Approach: Comparative Study of Lab and Field Results 63
3.13 Role of The Test Method in The Detection of Alkali-Silica Reactivity of Concrete Aggregates 64
3.14 Comparison Between ASTM C1567 and ASTM C227 to Reduce ASR 66
3.15 ASR of Alkali-Activated Concrete Determined by ASTM C1293 and 156768
3.16 Comparing the Ability of Admixtures to Mitigate ASR Using a Variety of Accelerated Methods.....69
3.17 Comparative Study of Short- and Long-Term ASR Tests Methods on Cementitious Materials 70
3.18 The Distinction Between Field and Laboratory Test Results for ASR 71
3.19 Accelerated Laboratory and Long-Term Studies Monitoring to Evaluate ASR 73

CHAPTER 4 CONCLUSION AND RECOMMENDATION.....75

REFERENCES.....81

CURRICULUM VITAE 85

NOMENCLATURE

AAC	Alkali-Activated Concrete
AAF	Alkali-Activated Fly Ash
AAR	Alkali-Aggregate Reaction
AAS	Alkali-Activated Slag
ACPT	Accelerated Concrete Prism Test
ACR	Alkali-Carbonate Reaction
AMBT	Accelerated Mortar Bar Test
ASR	Alkali-Silica Reaction
CCT	Concrete Cylindrical Test
CPT	Concrete Prism Test
MCPT	Miniature Concrete Prism Test
SCPT	Short-Term Concrete Prism Test
OPC	Ordinary Portland Cement
SCMs	Supplementary Cementitious Materials

LIST OF TABLES

Table 2.1 Calculation of Results of Particle Counts……15

Table 2.2 Electron Microprobe Analysis Results……...38

Table 2.3 (OH-) in suspensions maintained at 70 ℃……40

Table 2.4 (OH-) in suspensions maintained at 50 ℃……..40

LIST OF FIGURES

Figure 2.1 Effect of Calcium Hydroxide on Height Differential in Osmotic Cell Tests……21

Figure 2.2 shows the mean expansion of prisms made with different sand when stored in a NaCl solution…….……..28

Figure 2.3 Expansion of mortar bars autoclave-treated in an alkali solution ……...31

Figure 2.4 Display the petrographic analysis…….36

Figure 2.5 Show Microprobe quantitative analyzes…….37

Figure 2.6 Mortar Bars..……43

Figure 2.7 Length measurement of the specimens…….44

Figure 2.8 Test specimens for the study of developing a new method……..46

CHAPTER 1

INTRODUCTION

1.1 General

Within a few years of its completion, many structures constructed in California, USA, developed extreme cracking. Stanton showed in 1940 [1] that the alkaline-aggregate expansion reaction mainly caused this. It was demonstrated that high alkaline cement and opaline were used in these concrete structures. In several other nations, the cracking of concrete because of alkaline Silica was also known. In 1957, Swenson [1] reported another deterrent expansionary reaction called the alkali-carbonate reaction. There have been many international conferences discussing structural breakdown caused by an alkaline expansion in different world places. Alkaline expansion of aggregate, which typically results from the expansion of cement with reactive components in the aggregate particles, requires the chemical reaction between alkaline hydroxides. A third form, known as alkaline Silica, has been proposed in concrete containing argillite and greywacke, and the expansion reaction of alkaline silica and alkaline carbonate, which is generally slow to react, and the mechanism is not fully developed. Several publications detailing the potential mechanisms for alkaline aggregate reactions in detail were published. The pH of alkali is increased to 13.5-13.9 in the cement paste. The hydroxyl concentration of a concrete solution made of a high alkaline cement was ten times higher than that provided with low alkaline cement and 15 times more than a saturated $Ca(OH)_2$, respectively. Generally, the reaction in the first stage is carried out by the hydrolysis of the silica reactivity of OH to form alkaline silica gel and secondary overlap with the absorption of water through the gel, thereby increasing the amount.

Alkali's primary source is cement, but it cannot ignore the other sources. Additional sources include mixing water, marine water, and maybe some mineral components, including illitic clays, micas or feldspars, groundwater, deicing salts, and admixtures. The Silica of opal, cement/cryptocrystalline quartz, and others are natural materials known as alkaline reactive in concrete. Certain admixtures, including formulations

based upon $CaCl_2$ and super-plasticizers, can worsen the alkali-silica response. The expansion of the alkali silicate is the product of greywackes (feldspar or clay sandstone) aggregates and vermiculite exfoliates. Furthermore, phyllosilicates and other minerals react with alkaline solutions. However, the importance of those reactions remained unclear to alkaline-aggregate expansion with a high pH reaction involving silicates (zeolite and clay mineral).

The alkali carbonate answer is different from the other varieties in those large quantities of silica gel were not present in the concrete and the alkali expansion minerals in the aggregate are unknown. Mechanism specifics remain under discussion. The expansion of brucite crystals in the confined space of the dolomitization is attributed in one proposal, as follows:

$CaMg(CO_3)_2 + 2NaOH \rightarrow Mg(OH)_2 + CaCO_3 + Na_2CO_3$

$Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2NaOH$

The expansion is attributed to cryptocrystalline quartz is a further suggestion (Reactive alkali-silica is common in limestone). Gillot [1] attributed that the first expansion to the swelling pressure produced by moisture collection of fine components, dehydrated clay, is exposed to a de-dolomitization reaction. Whatever rock or mineral type, the growth of alkaline material, water, temperatures, and exposure times are affected by the expansion. The preventive measure against the expansion of alkaline aggregates is as follows. Not every unit is reactive, and these units are perhaps the right option. Nevertheless, reactive and marginally reactive aggregates encourage strong concrete mechanical characteristics which can be made available and used near the construction. With such aggregates, it may be appropriate to apply low alkaline cement and blend with additives. In general, it is understood that a slight expansion takes place under a certain quantity of alkali per m^3 of concrete made from the reactive aggregate. The theoretically low Na_2O (Na_2O equivalent= $Na_2O + 0.658\ K_2O$) contains alkaline in amounts less than 0.6 percent. Another way is to partially substitute Portland cement with fly ash, fume of Silica, slag of blast furnace, or ash of rice husk. It is yet to be resolved the impact on the alkaline expansion of reducing the w/c ratio in concrete. The lower w/c ratio provides improved strength, reduced porosity, lower

permitted permeability, and lower alkaline mobility. Nonetheless, the concentration of pore alkaline will rise. Air induction can minimize expansion by taking the reaction products into account. Some steps to mitigate alkaline expansion reactions include preventing admixtures containing large quantities of alkaline materials, usage a low content of cement. Some measures that minimize the alkaline aggregate expansion reactions are sealing concrete after sufficient time-lapse given for drying and the coating of aggregate particles with impermeable content, in particular lithium salts [1].

1.2 Alkali-Silica Reaction Mechanism

A hydrophilic gel substance referred to as alkaline-silica gel formed by the reaction of the alkaline pores in concrete and silica components of aggregated particles. As the gel absorbs water, the volume increases, and the pressure exerts sufficient to disturb concrete in most situations. In essence, the reaction takes four steps:

a) Hydroxyl (OH) attack dissolution of reactive Silica by breaking the bridges (Si - O - Si bonds) into weak, unstable bonds of silanol (Si - OH):

Si-O-Si + H_2O --> Si-OH...OH-Si

b) Reactions of the hydroxyl-ion silanol groups (additional hydroxylation):

Si-OH + OH --> Si-O + K_2O

c) Binding on negative sites of positively charged alkaline ions.

Alkali-silica gel silicate surface forming:

$H_{0.38}\,SiO_{2.19} + 0.38Na(K)_2O \rightarrow Na(K)_{0.38}SiO_{2.19} + 0.38\,H_2O$

Though its volume is larger than that of Silica, it is considered expansive and disturbs the structure's integrity. In the presence of water, substantial deleterious expansion occurs. The gel soaks water and has a strength of up to 11 MPa. The material breaks down as this pressure goes beyond or blends the tensile strength of the paste.

d) Establish a stable colloidal system (solvent): As water enters the system continuously, a gel solvent transition can occur, with a solvent from concrete cracks

exuding. Specific exchange reactions may occur, and in the soil-forming calcium silicate hydrate, calcium ions may supersede sodium and potassium ions [2].

1.3 Alkali-Silica Expansion Control Factors

Alkali-Silica is a dynamic phenomenon, which may be exacerbated by some correlated factors. The most important ones are:

The Nature of Reactive Silica: The ability of an aggregate as a criterion for reactivity rather than the rock type must concentrate attention on the minerals of the rock itself. By weight of the earth's crust, Silica is around 65 percent. Many forms of rock are silicon-containing. The alkaline-silica reaction includes not all forms of Silica but certain kinds. Crystalline, low-density silica polymorphs such as cristobalite and tridymite; improper, thermodynamically unstable shapes, like opal, Silica, chalcedony, etc., and deformed or strained quartz forms. The crystallinity and hydration status of Silica is usually related to reactivity.

Amount of Reactive Material: Experiments have shown that the reactive material in an inert aggregate leading to the full expansion has a certain content or proportion, known as pessimum content or proportion. In the case of opal, the pessimum proportion may be as low as 3-5%, while it may be 10-20% or even up to 100%, depending on the essence of the less reactive materials of aggregate.

Reactive Material particle size: There is a clear association between expanding alkaline Silica and aggregate size. There is not much study, however, and there is no consensus on this. Diamond reported that the expansion rates increase to 20 µm with decreased aggregate particle sizes. Mindess argued that the expansion of intermediate particles is the largest.

Content of alkali: Alkali, sodium, and potassium are the most popular. Elements are distributed in nature and present in limited quantities in all the raw materials used in the production of cement, and hence in cement. Usually, portland cement produces $Na_2O + K_2O$ of 0.5-1.3 percent. The content of alkaline portland cement shall be expressed as Na_2O_{eq}. The Na_2O_e is $Na_2O + 0.658K_2O$ and represents the weight of the same number of Na_2O moles, which correlates to the weight of K_2O. In cement, alkali

can be present in two different types: alkali condensing on clinker grain surfaces, which may be called sulfate salt, and alkali locked into the crystal-like structures. Both minerals of clinker can retain alkaline in a strong solution, but a significant proportion of C_3A sodium is present, whereas C_2S appears to disperse potassium more equally.

Humidity: Water is an integral component of a silica-alkaline response. It's the only transportation process for hydroxyl ions and alkaline ions. Alkali-silica gel often swells and exerts water intake pressure. Relative humidity (RH) has been shown to have a direct effect on the alkaline reaction. With an RH of 20 °C, 85% is adequate for the progress of a deleterious reaction, which is the estimated RH in the concrete. It is commonly assumed that if internal RH decreases below 75 percent, expansion is negligible.

Temperature: Higher temperatures speed up reaction development, but do not increase overall expansion, as is the case in most chemical reactions. Reaction and expansion start at high temperatures early and expand quickly, but both the reaction rate and expansion rate begin to slow. The reaction continues slowly at low temperatures, but expansion reaches the same degree that exceeds expansions at higher temperatures. High temperatures can improve silica solubility and thus facilitate a rapid reaction. On the other hand, at low temperatures, the migration of ions will slow down and result in a delayed expansion. The fast reaction can lead to early cracking, resulting in gels becoming lax with no further expansion. At slow reaction rates, the gel expanded, so further expansion is made [2].

1.4 Objectives of the Study

The principal objective of the study is to explain several common test methods for the alkali-silica reaction as the researchers have stated and to identify short- and long-term tests in this reaction (ASR) and evaluate the methods according to the limits to find the best test method if possible.

As a result, how accurate these test methods give. For example, ASTM C1260, chemicals used in the accelerated method, and how the damage caused by high temperature in cement mortar. When the same aggregate is used, the aggregate

expansion is lower in the long run. At the end of the accelerated test, a higher expansion of the aggregate was obtained and a wrong evaluation was made about the aggregate. At the same time, this study aims to determine new studies that determine Alkali silica test results in a short time. Understanding that new test methods will be needed from these experimental results.

1.5 Organization of the Thesis

This thesis will be divided into four chapters in addition to the references and as described below:

- Chapter 1: introduction to the Alkali-Silica Reaction and its mechanism and factors affecting it.
- Chapter 2: includes many of the common short-term and long-term methods in ASR experiments.
- Chapter 3: includes a literature review on some of the studies were conducted on silica-alkali reactions, depending on the available test methods and specifications.
- Chapter 4: includes the conclusion of the studies mentioned in Chapter 3.
- References.

CHAPTER 2

TEST METHODS FOR ALKALI-SILICA REACTION

In this chapter, 16 widely used ASR test methods will be presented with the objective to illustrate and discuss their significance, such as the conditions for each test method, the materials required to perform the examination, and the specific criteria for each test method to produce accurate and reliable results from that method. Further, some tables and figures will be included if necessary.

All laboratory test methods have a design to evaluate the alkali-silica reactivity of aggregates in concrete mixtures and measure the specific environment and the optimal mixing time ratio concerning the concrete's expansion.

Several tests had been used to accelerate the reaction in different ways to detect the ASR reaction in a shorter time. Every method has its design to measure the ASR expansion of the mortar and concrete samples. It should be noted that when the test conditions shift away from the actual environmental conditions that the concrete will face, the reliability of that test method comes into question. The following test methods are presented in chronological order.

2.1 The Test Method by T.E. Stanton

At the end of the 1930s, the California Highway Division first established the alkali-silica reactivity of aggregates in concrete mixtures from the research study undertaken by T.E. Stanton (1940). Started in1938, Stanton [3] continued his research on ASR reaction to determine aggregates' potentials for ASR for a half-decade. In the research studies, an ASR testing method was undertaken through the preparation of several specimens with nine different geometries and ratios, including mortar bars (25mm x 25mm x 250mm); concrete prisms (50mm x 50mm x 285mm with 1:1 Sand and Coarse aggregates; a maximum aggregate size up to 19 mm). The testing environment included continuous moisture, continuous drying, regular laboratory temperature, and moisture and alternative moisture and drying. The treatment methods used were Sealed containers, air, and water. The test period ranged from 28 days to five years.

The temperature of the test specimen was between (21.1 °C to 65.5 °C) and cycling heat and cooling in some cases. In his research studies, Stanton found that certain mineral elements, such as certain forms of shales and cherry found on the shores of California between Monterey Bay to the north and Los Angeles to the south, were theoretically suspected of triggering a harmful expansion of concrete due to some chemical reaction. The expansion was observed negligible if the alkaline content of cement was less than 0.6 percent. Another result was that the partial substitution by an appropriate pozzolanic content of high-alkali cement avoided excessive expansion. The ASTM C227 standard test method was based on his work (mortar-bar test procedure) [3].

2.2 ASTM C227 Mortar Bar Method

2.2.1 Scope

This test method [4] is based on the research work undertaken originally by Stanton, and it deals with measuring the combination of cement's susceptibility to expansionary reactions involving hydroxyl ions (sodium and potassium) in an alkaline environment by measuring the increasing or decreasing length of the mortar bars that contain the combination when stored under specified test conditions. Alkaline aggregates reactivity is classified into two groups:

- Alkali-Silica reactivity with certain silica, natural or artificial glasses.

- Alkali-Carbonate reactivity with dolomite, which includes some calcitic dolomites as well as limestone (see ASTM C294).

The approach is not recommended for detecting the latter reaction because the expansions produced by the alkali carbonate reaction during the mortar-bar test (see ASTM C586) are generally significantly lower than those produced by the ASR similarly harmful combinations in use.

2.2.2 Importance and usage

The results of tests conducted by this method include the possibility of a mixture of cement aggregates being able to generate harmful alkali-silica reactivity. Potentially deleterious reactive silica rocks, even if used a cement with high alkali content, result in negligible expansion because alkali-silica reactions are characterized by the low alkali-silica ratio that minimizes water consumption and swelling or the alkali release from bars by chemical methods. This test method does not yield a substantial expansion of dolomites deleterious to the alkali carbonate reaction if used in concrete for the coarse aggregates. In particular, Sulfates contained in the aggregate trigger an attack of sulfates on cement paste. If the results of the conducted tests indicate expansions beyond those found in Appendix C33, additional information is highly recommended to confirm that the expansion is caused by alkaline reactivity.

2.2.3 Temperature

The temperature of the room and dry materials must be kept at a temperature of neither less than 20 °C nor more than 27.5 °C. Water, wet shelves, wet space, and room in which measurements are carried out should be 23 ± 2 °C. The mold room's moisture content must be maintained at a minimum of 50%. Specification C511 applies to the moist wardrobe or bed. The storage space in which the container samples are maintained shall be 38 ± 2 °C.

2.2.4 Procedure

For each mixture of cement aggregates, make four or more test specimens, two of each two batches, and prepare the molds according to the C490 Design specifications.

Divide dry materials of test mortar by weight as 1 to 2.25 parts cement: classified aggregate. A flow rate between 105 to 120 (as calculated by test method C1437) shall be determined in millimeters of the mixing water, Mix the mortar according to practice C305 specifications, and the molding test specimens are returned from the flow table to the mixing bowl immediately after completion of the flow test.

2.2.5 Calculation of Expansion

Calculate at each measurement time the difference between the specimen's initial length and the length at the closest 0.001 percent and record the specimen expansion during that period. Report the expansion average by combining the four specimen units for a given time to the nearest 0.01%.

2.2.6 Precision of Test

It is considered satisfactory when the difference in the percentage expansion rate of each specimen provided in a group is not greater than 0.003. When the average expansion is greater than 0.020 percent, replaceability is considered satisfactory. The expansion in percentages of each specimen molded on the same cemeteries the replacement ability of the specimen in a group is considered acceptable [4].

2.3 ASTM C289 Chemical Test Method

2.3.1 Scope

This test method [5] deals during a chemical assessing, utilizing a 24 h response rate at 80 °C at 1 N caustic soda solution and aggregates crushed and sieved on 300- μm sieve and remain on 150- μm sieve, of the possible reactivity of an aggregate with alkali during a hydraulic cement concrete.

2.3.2 Significance and Use

In conjunction with other approaches, this process is employed to assess silicon reactivity in aggregates with alkaline in hydraulic concrete. Reactions within the aggregate between an answer of caustic soda and silicon components were shown to contribute to the behavior of such aggregates in concrete structures. The test results are often easily obtained, and while not entirely accurate, useful data are often given.

2.3.3 Procedure

Weigh three dry specimens 25 ± 0.05 g parts of 150-μm to 300-μm. Apply 25mL of 1 N NaOH solution using a pipet. Screen and gently swirl all four containers to release

the trapped air. Place all containers at 80 ± 1.0 °C liquid bath immediately following the sealing of the bottle. Take the bathtub containers off after 24 ± 1⁄4 h and cool them for 15 ± 2 minutes, with a temperature below 30 °C under running tap water. Apply the vacuum and set it to around 51 Kpa. Continue filtering until an average of 1 drop every 10 seconds of filtrate is obtained. Apply vacuum for a period equal to the three specimens' total filtration time, then take 10 ml of the filter by the pipet and dilute in a volumetric flask of water 200 ml immediately after completing the filtration. For evaluating the dissolved SiO_2 and reducing alkalinity, reserve this diluted solution. If the diluted filtrate does not require analysis 4 hours after filtration completion, Move the solution to a clean and dry polyethylene jar and seal with a stopper, cap, or lid.

2.3.4 Filtrate Analysis

Calculate diluted silica by the gravimetric or photometric process and measure alkalinity reduction.

- **Dissolved Gravimetric Silica:** measure the Concentration of SiO_2 in NaOH from the accumulated content as:

$$S_c = 3330 \times W \quad \textbf{(2.1)}$$

where:

S_c = SiO_2 concentration (mmol/L)

W = SiO_2 (grams) in 100 mL of solution

- **Dissolved Photometric Silica:** This method applies in all water solutions except for those with unnecessary interference, but it will not compute the overall amount of silica to determine crystalloid (noncolloidal) silica. The method can be used particularly when the crystalloid silica is under 10 ppm in rapid control analysis.

Estimate concentration of SiO_2 in NaOH solution from aggregate ingredients:

$$S_c = 20 \times (100/V) \times C \quad \textbf{(2.2)}$$

where:

S_c = SiO_2 concentration (mmol/L).

C = silica concentration (mmol/L) in solution as determined by a photometer.

V = dilute solution (mm).

- **Alkalinity Reduction:** Pipet transfer of a 20-ml dilute solution aliquot to a flask of 125 mL Erlenmeyer, 2-3 phenolphthalein drops, titrating to the 0.05 N HCl endpoint. Calculation: Compute alkalinity reduction in the following:

$$R_c = (20N/V1) \times (V3-V2) \times 1000 \quad \textbf{(2.3)}$$

where:

R_c = alkalinity reduction (mmol/L).

N = HCl normality used to titrate.

V1 = dilute solution (mm).

V2 = HCl in (mm) to attain the endpoint in the specimen.

V3 = HCl in (mm) to attain the endpoint in the void.

2.3.5 Accuracy

Preliminary precise data suggest that if the value of the 3 values of Rc (and Sc) does not vary from the 3 values of the mean.

1. if the mean is ≤ 100 mmol, 12 mmol/L.

2. if the mean > 100 mmol/L, 12 percent [5].

2.4 ASTM C342 Volume Variation of Cement-Aggregate Composites Test

This testing process is essentially a modified mortar bar test to determine the potential expansion of a given combination of cement aggregates based on many mechanisms such as ASR. It was mostly used for aggregate study in several USA cities. The test includes sending mortar bars to various moisture and temperature storage conditions and measuring lengths up to one year annually. ASTM C342 states that for this procedure that no expansion acceptance restrictions have been laid down. However, the work of the ASTM sub-committee suggested that expansion of 0.020 percent or more after one year could be unacceptably expanded by alkali-silica reactions. In 2001, ASTM C342 was withdrawn [6].

2.5 ASTM C295 Petrographic Test

2.5.1 Scope

This guidance method [7] details the procedures used as aggregates in cement mixtures for petrographic analyses of the samples representing materials suggested for use in the manufacture of aggregates. It describes the degree that petrographic tests must use, the selection, and properties to test concrete aggregate samples.

2.5.2 Method Summary

Usually, the test would require the employment of optical microscopy. The full petrographic test can include examining aggregates or elect constituents by suggesting different processes, such as XRD, DTA, SEM, EDX analysis, or infrared spectroscopy. Identifying the sample components is often a critical step towards recognizing the properties expected to affect the fabric's behavior when used.

2.5.3 Significance and Use

Petrographic tests are conducted to determine the material characteristics, describe the sample components and identify them, determine the proportions of relative sample components that are important to proper sample analysis, and compare aggregate samples from new sources with mixture samples from one or other sources. The petrographic exam should assess if the aggregate contains chemically volumetrically unstable minerals or materials. The quartz content of concrete aggregates could be subject to high temperatures. The conversion to beta-quartz could be restricted to requirements at 573 °C with an increased volume.

2.5.5 Calculation of Sieves Distribution

Compute the composition and weighted average distribution of each sieve in a non-homogeneous sample in the following way: Specify the distribution of each sieve by adding the entire variety of particles of that sieve and arranging each component as part of the total quantity (as % particles). The percent of components in the sieve multiplying by the percentage of the sieve fractions in the whole sample above that

size. By adding the calculated percentages in each sieve fraction, obtain the weighted portion of each component in the sample (see Table 2.1).

As a convention, every seven fractions of the sum and every sieve sample are 100% trace-free. To be evident, the components known to deleteriously react in concrete should be tabled, even if the volume in a sample or a fraction is minimal [7].

Table 2.1 Calculation of Results of Particle Counts (Guide ASTM C295 page7, See reference [7])

Individual Percentage Retained on Sieve	Composition of Fractions Retained on Sieve Shown below							
	19 mm		12.5 mm		9.5 mm		4.75 mm	
	17.4		32.6		29.5		20.5	
Constituents	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%
A1	250	50	200	40	150	30	50	10
A2	50	10	100	20	125	25	100	20
A3	10	2	50	10	75	15	100	20
B1	107	21.4	70	14	62	12.4	32	6.4
B2	76	15.2	53	10.6	19	3.8	87	17.4
B3	---	---	20	4	43	8.6	96	19.2
C1	5	1	5	1	20	4	20	4
C2	2	0.4	2	0.4	6	1.2	10	2
C3	---	---	---	---	---	---	5	1
Total	500	100	500	100	500	100	500	100

		Weighted Percentage of Constituents in Each sieve Fraction				Weighted Composition of Sample		
		19 mm	12.5 mm	9.5 mm	4.75 mm			
A1		8.7	13	8.9	2.1	32.7	64.6 (Total A)	
A2		1.7	6.5	7.4	4.1	19.7		
A3		0.4	3.3	4.4	4.1	12.2		
B1		3.7	4.6	3.7	1.3	13.3	31.8 (Total B)	
B2		2.6	3.5	1.1	3.6	10.8		
B3		---	1.3	2.5	3.9	7.7		
C1		0.2	0.3	1.2	0.8	2.5	3.6 (Total C)	
C2		0.1	0.1	0.3	0.4	0.9		
C3		---	---	---	0.2	0.2		
Total in Sieve Fraction		17.4	32.6	29.5	20.5			
Total in Sample, Condition 1						48.5		
Total in Sample, Condition 2						31.4		
Total in Sample, Condition 3						20.1		

2.6 ASTM C1293 Concrete Prism Test

2.6.1 Scope

This test deals [8] with determining the susceptibleness of the associated mixture of pozzolan or scoria to take part in ASR by measuring modification of concrete prism length.

2.6.2 Importance and Use

The findings use to determine the minimum quantities of the species pozzolan or slag necessary to avoid harm extension when measuring an aggregate using pozzolan or slag. This testing method is developed to evaluate the conduct of aggregates with an alkali Portland concrete of 5.25 kg/m^3 or pozzolan or alkaline including concrete with a proportionally reduced content from 5.25 kg/m^3 Na_2O equal to the volume of Portland cement in pozzolan or slag. Following compliance with ASTM C856, a petrographic examination of concrete prisms should be conducted to validate the presence of known reactive ingredients and to classify alkali-silica products.

2.6.3 Procedure

Initial Reading Comparator follows the C157/C157M test system protocol except for saturated lime water. In the reservoir inside the storage container, no water contact shall be made with the samples. The following readings must be necessary for the test of a compound at the time of the expansive alkaline reaction at the aggregate at the age of 28 and 56 and also at 3, 6, 9, and 12 months and for the testing of compounds with pozzolans or scratch at an additional time of 18 and 24 months. Remove containers that carry prisms from the temperature environment 38 ± 2 °C and position them at 23 ± 2 °C for 16 ± 4 h before reading in a temperature-controlled environment. All specimens in the container are simultaneously read for comparators.

2.6.4 Calculation of Expansion

Measure the length difference between the initial specimen reading and the reading at each interval, and record as long as the change in length of prism for that time, at the nearest 0.001 percent for the category of prisms at age measure the average percent length change.

For valid tests at that age, at least data are accessible of three bars at any age.

2.6.5 Accuracy

- Accuracy Through Several Laboratories: Average Expansion < 0.014%: the single test result (mean three prisms value) of midlevel expansion in low to 0.014 percent for the midsection is shown to have a standard deviation of 0.0032 percent for an average extension, lower than 0.014 percent for mean 3 times compared in mean group time and measurements (CSA A23.2-14A).

The outcomes of two properly performed experiments on the same aggregate should therefore not vary by more than 0.009 percent in separate laboratories, 19 out of 20.

Average expansion > 0.014%: 23 percent was found to be multi-laboratory variance coefficient of single test result (mean of measuring three prisms) (CSA A23.2-14A). Consequently, the outcomes of two proper experiments performed on the same aggregate in separate laboratories cannot vary by over 65% on average, 19 times out of 20.

- Accuracy Through One Laboratory: Average expansion < 0.02%: The multi-specimen standard deviation is 0.0025 (CSA A23.2-14A). The range of the three individual prism measurements (the difference between higher and lowest). In computing an average test result, nineteen times out of twenty does not surpass 0.008 percent.

Average expansion > 0.02%: The multi-specimen standard deviation within the laboratory is defined as 12% for average expansions exceeding 0.02% (CSA A23.2-14A).

The average test results are not greater than 40% of the average, 19 times of 20, of three individual prism measures used to measure the average test outcomes.

Bias: Because the materials used for evaluating this test method's bias are not accepted, no declaration is made [8].

2.7 Osmotic Cells Tests

Verbeck and Gramlich [9] developed an easy approach combining ASR's physical and chemical effects. Its use removes the mechanical effects of materials complicating mortar and concrete test results, analyzes those variables, and specifically observes and monitors certain chemical and physical elements of the reaction mechanism.

Stark and Schmitt have made recent progress in developing the test to assess aggregate reactivity potential. Verbeck and Gramlich used the test to assess the effects of solid calcium hydroxide concentration and other variables within the reaction mix in sodium hydroxide solutions.

In these tests, the reaction mixture in the reaction chamber 12 ml was separated by a hardened cement pulse membrane, containing equal amounts of the solution and solid calcium hydroxide but no reactive aggregate. Capillary tubes connected to each chamber allowed measurements, the dissolution, the reaction, and transport of the solution needed to eliminate concentration and differences in osmotic pressure of the volume changes in each chamber. The reaction products formed, soaked water, sprung up and carried fluid to the reaction chamber from the reservoir chamber.

Figure 2.1 indicates the effects of 4-grams No. 50-No. 100 Opal 70 samples (300-150 mm). Without $Ca(OH)_2$ for 3% NaOH solution, the key consequence of reactions is that reaction products are absorbed solutions. Initially, the reaction chamber volume decreased because of certain dissolution and reaction of the opal and reverse surfaces due to a decrease in the solution concentration of the reaction chamber.

The rates of swelling of reaction products prevailed after several days, and flow into the reaction chamber continued to remain for a couple of weeks. The results of blending different quantities (less than 45 mm) of calcium and opal were to gradually decrease the rate of flow until a flow to the reaction chamber was stopped with the addition of 3 grams. The following work showed that after a certain further delay, the flow could begin.

The fluctuations in calcium hydroxide quantities were not obvious to Verbeck and Gramlich. They argued that the solubility and reactivity of 2 or 3 grams of calcium hydroxide were higher than both and attributed it to supposed low calcium ion motion.

- Osmotic Cells Tests Results:

1. A surface reaction occurs after a rather opal dissolution followed by continued penetration and reaction of C-N-S-H or N-S-H with OH-, Na+, and Ca++ ions.

2. Volume changes due to dissolution, reaction, and fluid flow are all accounted for in the volume measurements for each room.

3. Silk ions are present in cement pastes of less than 0.5 w/c. This paste allows water, sodium hydroxide solution, and ions to flow freely.

4. Figure 2.1 does not indicate a "safe" reaction in the tests without solid calcium hydroxide; the solution penetrates, dilutes partially, and swells the opals with time to growing depths. Water molecules initially disperse Na+ and OH- ions to the reaction room to achieve an equal activity for every solution. Diffusion of a solvent onto swelling opal molecules results in the formation of swelling N-S-H-gel determines a steady outflow into the reaction chamber. In both chambers, the pH and Na+ levels decrease.

5. A healthy reaction time initially occurs with solid calcium hydroxide; On the surfaces of opal grains, some silica dissolves and precipitates C-N-S-H; OH, Na+, and Ca++ penetrate and react with the silica in the internal region to form C-N-S-H. Dissolution and reaction shift in negative volumes and the diffusion of water and ions into the room.

6. If there is a lack of hydroxide in the Reaction chamber, reaction matter in the opal molecules starts to become an almost N-S-H-swell gel over the response line. C-N-S-H, which was already developed, starts swelling gel as it supplies the new product with calcium. The diffusion of the solution through swelling opal particles, as in point 4, establishes a steady flow into the reaction chamber.

7. Calcium hydroxide rises in the reacted opal surface, causing thicker C-N-S-H layers and slowing the swelling onset and flow into the reacting chamber.

8. The constant flow rate based on:

a. The densities of the surface reacted to which ions, OH-, Na+ and water would penetrate.

b. The unreacted opal quantities.

The main cause for the slope variations of the almost linear curve sections in figure 2.1 is assumed to be these two factors. This figure and others from the same document now indicate that the findings are entirely in line with Powers and Steinour's ASR model. Therefore, when the calcium hydroxide was sufficient to prevent reaction room flow, no swelling reaction product was present. Verbeck and Gramlich presented strong evidence for the creation of non-swelling reaction components in the opal. The time is taken to react to the depth where calcium ions do not penetrate as quickly as NaOH ions delay inflow into the reaction chamber during experiments with enough calcium hydroxide. In mortar bar tests, the relation of the time delay in the Osmotic Cell Test and pore solutions can be affected by the diffusion rates beyond the reactive aggregate where the reaction is in the rate-limiting stage [9].

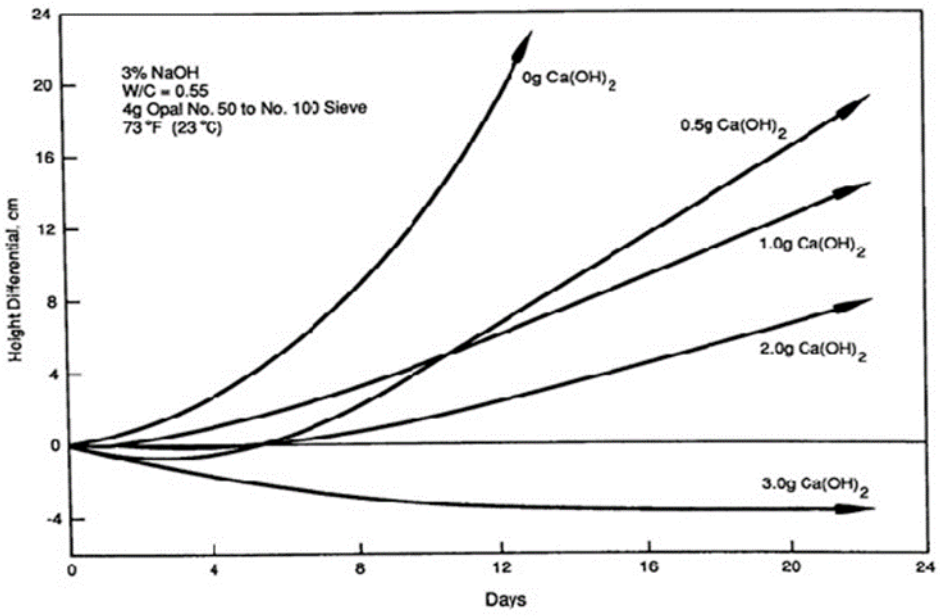


Figure 2.1 $Ca(OH)_2$ Influence on Height Differential (David Stark, Sidney Diamond, and Micheline Moranville-Regourd Study, See reference [9])

2.8 Gel Pat Test GPT

2.8.1 Scope

Various qualitative experiments [10] were proposed to assess potential alkali-silica reactivity by gel formation in a solid alkali solution of minerals and rock particles. After a relaxed wet-room treatment, the surface of the pat is torn to release the particles. It is then plunged into a closed container with a calcareous alkaline hydroxide solution and polished face-up. The gel pat test (GPT) was highly efficient in generating an abundant amount of gel from the reactive opal bearing aggregates measured at room temperature in five days. Furthermore, the increased conditioning temperature of a series of selected reactive aggregates to 54 °C produced a comparable amount of gel after only 16-17 h, compared with 21 °C for one week.

2.8.2 GPT Objectives

This test presents the study results to assess the capacity of GPT to evaluate, to some degree, the potential ASR of aggregates in the St. Lawrence Lowlands but, most

importantly, to provide details that could clarify variations of the expansive behavior of the different caliber and limestone aggregates. The effects of the standard and rapid laboratory tests and field output are correlated with the behavior of the aggregates.

2.8.3 Limits of the Testing Program

A variety of laboratory tests were used to determine the possible reactivity of alkali-silica in 65 limestone and dolostone aggregates tested in this analysis. The field and laboratory survey for many aggregates has led us to propose the requirements for the following limit:

(1) Non-reactive: expansion of concrete prism < 0.04% (after 1 year).

(2) A slightly reactive: 0.04% < expansion of concrete prism < 0.06% after year expansion.

(3) Reactive: expansion of concrete prism > 0.06% after one year.

2.8.4 Conclusions of GPT

The majority of the dolostones studied, including those from the Chazy and Beekmantown groups, even those from the Trenton Group of limestones, contained lower than 5% insoluble residuals, did not generate gel nor trace in this test GPT<0.10. Less than 25% of the aggregate weight of the specimens contained gel deposits.

There has been evidence of the concrete expansion in the Neuville formation of the Upper Trenton, extending from central to eastern St. Lawrence lowlands, exceeding the suggested limit of 0.04 percent, and the deleterious output in this area. Both specimens of these rocks analyzed in this sample had GPT values greater than 1.10, 89% containing at least 75% of the gel deposits. Indeed, for specimens with higher dissolved silica values obtained with changed chemistry, higher GPT ratings have often been recorded.

The large proportion of molecules displaying a gel deposit examined reactive limestones of Trenton indicates that the responsive phase in these rocks is distributed over the majority of the tested beds stratigraphically levels and not concentrated on

the minimal number of highly reactive beds. The responsive phase seems to be microcrystalline to quartz cryptocracy.

The expansion in CPT (CSA A23.2) and the accelerated NBRI test (ASTM C9) showed that, despite the substantial dispersion in the information, there was a reasonably positive relationship to the amount of gel provided by the appropriate gel pat test specimens. However, when the particles are confined to concrete, other variables such as porosity and permeability affect the mechanism, such as changing the reaction rate [10].

2.9 ASTM C586 Rock Cylinder Test Method

2.9.1 Scope

This method [11] includes the assessment of the expansion of the carbonate rock specimen at the room temperature of a NaOH solution. During this immersion, the variations in length show the overall rock reactivity and whether the effect of aggregate preparations of the rock on changes in concrete volume should be checked.

2.9.2 Importance and Usage

This test procedure aims to provide a reasonably rapid indication that some carbonate rocks can use as a possible expansive reactivity of concrete aggregates. The evaluation method should not be used as the basis for a specification but should be a method of testing and screening. Two types of AAR are identified:

(a)ASR involving some rock-and-silica. (b) alkali-carbonate reactivity involving dolomite, limestone, and dolostone. This test is not appropriate for alkali-silica reaction detection.

2.9.3 Procedure

- Place a specimen mark and measure the specimen length.

- Take the sample to a room temperature of 20 - 27.5 °C into distilled water.

- Take the specimen, extract the excess surface water by a blot at intervals, and measure up to 0.02% as measured in 2.9.9 below before a length change over a 24-hour immersion cycle. The reference length is usually reached after one to four immersion days.

- Take the specimens with water-saturated, at room temperature and size, in a container that Contains at least 35 mL of NaOH per sample solution.

- Calculating 4 weeks after 7, 14, 21, and 28 NaOH-solution immersion days. If the experiments last 1 year, measurements take place at intervals of 12 weeks.

- Remove the specimen from the bottle when tests are carried out by distilling water rinse, extracting surface water from the container, and calculating its length in the same position as the original one.

- Return the sample to the jar and reseal directly after weighing.

- Replace the solution for the evaluation cycle every 6 months.

2.9.4 Calculation of Length Change

The length change is measured as follows to 0.01% of the length as:

$$\Delta l = [(l1 - l0)/ l0] \times 100 \quad \textbf{(2.4)}$$

Δl = **%**Change of length during test age.

$l1$= mm (in.) length at the age of evaluation.

$l0$= Water equilibrium reference length.

2.9.5 Precision

When the repeated results determined by the same operator, representing probably the same substances, vary by greater than 0.10% for expansions of lower than 1.0 percent; therefore, rocks with substantially different chemical compositions and textures are highly probable.

A specific laboratory examines the variety of cylinder measurements of 29 different rock sources (approximately 75mm x 75mm x 50mm in size for each pair of cylinders cut from a different sample block).

The standard deviation was found to be 0.0255 percent for pairs of a specimen with an average expansion of less than 0.5 percent; thus, the expansion gap between pairs of single block cylinders is only 0.072 percent one time in a decade where the average expansion is below 0.5 percent. While the standard deviation was found at 0.095 percent for specimens with an average expansion of over 0.50 percent and just 0.269 percent once every twenty years for pairs of cylinders if the average expansion is greater than 0.5% [11].

2.10 Nordtest Accelerated Alkali-Silica Reactivity Test

2.10.1 Scope

An accelerated test method for detecting potential alkaline aggregate reactivities has been suggested. The product is 1:3 of cement prisms from sand, and the prisms are saturated with 50 °C in the NaCl solution. Measurement of longitudinal shift with time indicates the alkaline reactivity potentials of aggregates. The core components of a new section of the road have been put in water and a NaCl solution during the initial testing steps for the initial postulations. Both were held at 50 °C, which pavements could have easily reached. Cracks and other signs of alkaline aggregate reaction formed in the solution of NaCl within 3 weeks.

2.10.2 Procedure

A comprehensive work program was introduced, as an accelerated method to detect alkaline aggregate reactivity of sand and stone. It is considered to be of interest to other workers, given the positive results to date and the technical simplicity. There were three sand types: ISO Standard Sand, Nymolle Sand fraction 0-4 mm, standard sand 50:50, Pyrex crushed glass, and low alkaline Portland cement was used.

Three lots of mortar were made from the above raw materials. These mixes had a 1:2:0.5 cement:sand:water ratio, 40 mm x 40 mm x 160 mm prisms have been cast out of each of these mixes. The prisms were split into two groups after 28 days of water healing so that at least two prisms of each of the mixes were included in each group. One group has been put in the water and the second in a saturated NaCl solution after their initial measurements of the duration. At 50 °C, they both kept the solutions. These prisms were cooled to 20°C weekly and weighed in their solution. Simultaneous visual inspection of the prisms was performed. The prisms then came back to the hot pools.

2.10.3 Results and Discussion of Nordtest Method

Even after 14 weeks of storage, the prisms stored in water did not display any sign of deterioration. The median expansion was around 0.08% and did not differ significantly between the mixes. The findings of this research support the low alkali cement use. Figure 2.2 displays the medium-length changes of various batch prisms contained in the NaCl solution. There was a gradual but minor expansion of the prisms found in ISO sand to the point of stoppage and no signs of side effects. The prisms, including Nymolle sand and Pyrex, were substantially increased by the third and sixth weeks, respectively, and substantial cracking occurred. It reveals that there are optical and microscopic elements in the prisms. Since the other parameters were the same, variations can be attributed only to their respective sand forms of the prism expansion of various mixes in the saturated NaCl solution.

The Nymolle sand contains approximately 8 percent opaline silica, which is well known. Crushed Pyrex is an all-alkali-silica reactivity test standard aggregate. Any alkaline reactive silica failed to display a petrographic analysis of ISO sand. In the above cases, we can reasonably conclude that prisms extend and subsequently break, i.e., that the alkaline-aggregate reaction results in the presence of alkali-silica reactivity in the sand forms. Using the low alkaline cement of Portland prevented the possible supply of cement to the required alkali. The presence of a saturated NaCl solution would therefore seem to have somehow intensified the alkaline aggregate reactions in the Nymolle sand-crushed prisms of Pyrex. The findings lead to earlier

Stanton observations on the excessive expansion of NaCl excessive expansion when coated with reactive aggregates and low alkaline cement.

Further testing demonstrated that the above speedy test could be conducted at 40, 50 °C, but cracks take longer at 40 °C than at 50 °C. So far, ten sand samples with positive correlations have been used to examine this approach. In their current configuration, the test involves (1) the aggregates to pass 4 mm of a sieve, (2) a cement mortar cumulative ratio 1:3, (3) prism 40mm x 40mm x 160mm with reference points, (4) 28 days of curing by water, (5) the prisms being put at 50 °C in a saturated NaCl solution, and (6) the calculation of their changes in length. A comparative test strategy can be described by adhering strictly to a fixed size classification of aggregates [12].

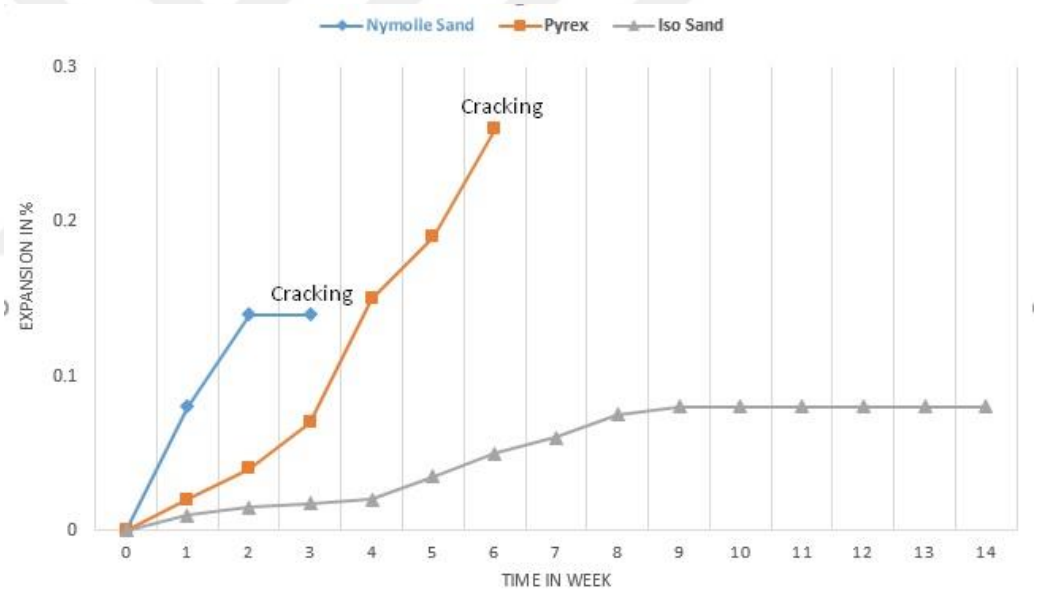


Figure 2.2 The expansion of prisms in a NaCl (Cement and Concrete Research. Vol. 8, No.5, p. 649, 1978, See reference [12])

2.11 Japanese Industrial Standard JIS A1146

2.11.1 Scope

This method [13] calculates the alkaline-silica reactivity of the aggregates by measuring changes in mortar bar length. The test method (in the following called the

mortar bar method) is defined. However, the concrete aggregate cannot be used for artificial lightweight aggregates (coarse, fine).

Note: In 3.1 of JIS A1145 are defined terms and definitions of the alkaline silica reaction (ASR).

2.11.2 Humidity and Temperature

The mortar molding chamber and the chamber of measurement adjustment in length are held at 20 ± 3 °C. The temperature is kept at 40 ± 2 °C in the container, and relative humidity is maintained at or greater than 95%.

2.11.3 Initial Curing

Put the whole mold in a humidity box for up to 24 ± 2 hours after kneading, do not touch the mortar surface to dry the cover with a wet cloth and initially cure. The mold is removed after the initial treatment.

2.11.4 Storage and Measurement

Specimens are stored in storage containers, as a way of ensuring a relative humidity of 95 percent or higher, it is preferable to cover the surface of the specimen with absorbent paper or a wet cloth that maintains moisture to the extent that it does not leak. When the specimen achieves the appropriate age, take the specimen from the storage room or box together with the container, keep it at 20 ± 3 °C for 16 hours or more, open the container, and measure the change in the length of the specimen. Immediately after measurement, return to 40 ± 2 °C and relative humidity of 95 percent or more.

2.11.5 Expansion Coefficient Estimation

The expansion coefficient for the specimen is measured up to 0.001 percent under Clause 6 of JIS A 1129-3 and reported during this time.

2.11.6 Accuracy

If an average expansion rate is measured at 0.001% for three test samples molded out of the same lot and the "average expansion rate" is set, it can be seen that the exactness

is fulfilled if any single sample expansion rate is within the range of (Average expansion rate ± 0.010%). However, the average growth rate reaches 0.050 percent, the accuracy of each expansion test sample can be considered to be achieved if the expansion rate of each test sample is 0.8-1.2 times. The three displayed an improvement of 0.100% or more irrespective of the exactness.

In addition to this, the average value of the other two except one which has not expanded the most can be calculated if the accuracy condition is not compatible with either of the above.

2.11.8 Judgment of ASR of Aggregate

The judgment of ASR of aggregate is judged as "harmless" when the average coefficient of expansion of three specimens is less than 0.1% at 26 weeks of age and "harmful" when it is 0.1% or more. If the material to be measured shows an expansion of 0.05% or more at 13 weeks of age, it may be considered "harmful" at that time. In that case, the measurement at the age of 26 weeks may be omitted. If the material age is 13 weeks and less than 0.05%, it should not be judged as "harmless" at that time and should be judged after continuing the test until the material age of 26 weeks [13].

2.12 AAR Rapid Identification Method

2.12.1 Scope

The alkaline aggregate reactivity can be measured in expansion quantitatively, but typically the findings are got within 6 months to 1 year (or at least 3 months) [14].

Thus, various techniques, such as the increase in the cement's alkaline content or the cement to aggregate ratio and NaCl solution bars storage were studied to speed up the alkaline-silica reaction. However, there is also a general inference that the results acquired at temperatures above 37.8 °C tend to have not been accurate, even though several experiments were carried out to expand the alkali-silica reactions by increasing temperatures. The standard temperature is thus to be carried out at 37.8 °C for the alkaline-silica expansion test.

The authors have constructed the mortar bars to be stored instead in humid containers and water; therefore, they found that expansion values could be increased dramatically. If replaced alkaline hydroxide solution with water, the values can be increased. By this process, it can entirely be stopped from releasing alkali from mortar bars into water. Therefore, it has examined the extension of mortar bars in alkali hydroxide at varying temperatures by autoclave treatment, and we have thus obtained a new accelerated process, and the efficiency of the process on different types of rocks and minerals has been investigated.

2.12.2 Experimental Method

During the entire test, 1cm x 1cm x 4cm molds and a low alkaline cement were used. By addition KOH during the blending, the balance of the alkali was completed. The principal aggregates used were:

1. Opal, which is SiO_2 amorphous. In the ASTM C289-71 test protocol, R_c had been found 184.4 mM/l and Sc 1160 mM/l. Results show that opal is highly alkaline.

2. Perlite includes many minerals such as volcanic glass, small quantities of feldspar, and mica with medium alkaline reactivity. R_c found 370.8 mM/l, and Sc found 510.5 mM/l.

3. The default sand used for strength testing in China is quartz sand or crystal quartz. Certain of the crystals are undulating. R_c is found at 19.6 mM/l, and Sc was 31.6 mM/l. Quartz sand is considered a non-reactive aggregate.

2.12.3 Experimental Results and Discussion

Via several experiments found that the autoclave-treated mortar bars in the alkaline hydroxide solution can accelerate ASR and enhance the expansion value. However, the autoclaving temperature is the most susceptible factor to the alkali-silica reaction. The expansion of quartz powder, perlite, and opal mortar bars, as shown in figure 2.3, Where the test conditions of:

1) As follows: 1cm x 1cm x 4cm of mortar bar; 10:1 of cement: aggregates; 0.15-0.75 mm of aggregate size; 0.30 of w/c, and + 1.5% of cement alkali. Na_2O. The mortar

bars will remove from the molds and then cured for 4 hours in 100 °C steam from a day of curing, then put into 10 percent KOH and autoclave solution and 6 hours of treatment at various temperatures.

2) were essentially handled similarly, except for a 1.72 percent equivalent alkali material. Na_2O and the KOH solution concentration was 24%. From figure 2.3, 150 °C for autoclave treatment based on these experiments was chosen as the optimal temperature.

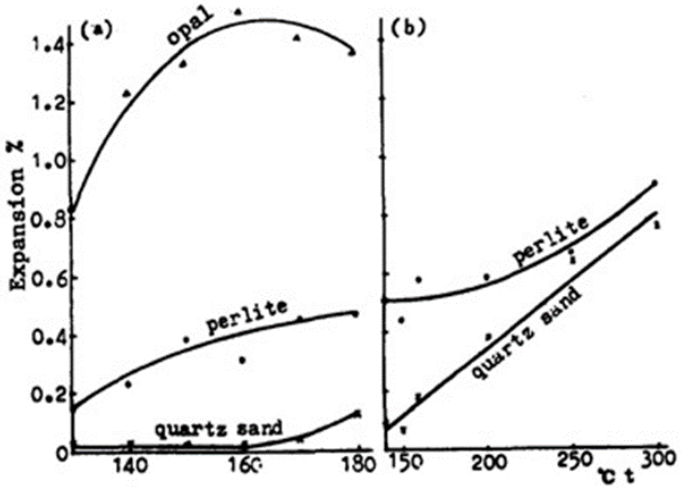


Figure 2.3 Autoclave-treated bars expansion (by Tang Ming-Shu and others, See reference [14])

The results show that the expansion values in cement paste and quartz sand for mortar bar expansion were minimal and that autoclaves were processed at 150 °C (sometimes just 0.02%). However, the reactive aggregate expansion values were at least 0.105%, with most of the above 0.25%. It should be concluded that alkaline solution with mortar bars autoclaved to 150 °C to detect all reactive rocks and minerals. Experiments showed that testing findings are reliable to a certain degree, both in ASTM C289-71 and in the fast process. The results of the non-reactive aggregates test show that non-reactive aggregate expansion values are approximately identical to those of reference specimens. Experiments have also been shown to be compatible in

a large degree with those of ASTM C289-71 and ASTM C227-71 in the accelerated test performance.

2.12.4 Conclusion of AAR Rapid Identification Method

1. In two days, it can also be easily achieved in practice by defining the alkaline reactivity of the aggregate.

2. The combination of the quick approach with the microscope observation helps explain the unexplained alkaline-aggregate reaction mechanism [14].

2.13 ASTM C1260 Mortar Bar Test

2.13.1 Scope

This standard method [15] allows the identification of deleterious aggregate reactions in mortar bars during 16 days.

2.13.2 Importance and Usage

This method of assessment provides a way of detecting the potentially dangerous inner expansion of an aggregate intended for concrete used to undergo an alkaline-silica reaction. The testing system is based on The NBRI accelerated. The cement's alkaline content does not influence expansion since the samples are subjected to the NaOH solution.

Additional information sources include:

a) a petrographic analysis (guide C295/C295M) of the aggregate to decide if there are recognized reactive components.

b) the testing of samples after the testing of alkaline reaction products (Practice C856).

c) field service reports can be used for performance evaluation, as long as they are available.

Using mitigative steps such as lower alkaline cement, mineral admixtures, or granulated soil slag will be assessed when results of tests are carried out using that test method and additional knowledge that such aggregates are to be considered deleteriously potentially reactive.

2.13.3 Conditioning

- Maintain molding room temperature and dry materials at 20 °C and, not more. The mixing water and wet room temperatures shall not differ by more than 2 °C from 23 °C.

- Maintain at not less than 50% relative humidity of the molding room. The humid closet or room must comply with ASTM C511.

- Hold the oven or bath where the samples will be kept at 80 ± 2 °C and stored in the containers.

2.13.4 Procedure

Storage and reading initial: Store each mold inside the moist cabinet. The specimens are kept for 24 ± 2 h in the molds. For dipping specimens, the water temperature shall be 23 ± 2 °C. Seal the containers in the furnace or water bath at 80 ± 2 °C and position them for 24 hours.

Subsequent store and measurement: Take periodic comparator readings of at least 3 intermediate readings for at least 14 days after zero reading at around the same time per day.

2.13.5 Calculation of Expansion

As the specimen increases by the next 0.0001%, the difference between the zero-comparative reading of the specimen and the reading at each point is reported as an appropriate measurement length. State the combination of three specimens of a specific cement-aggregate mix analog expansion at the close of 0.01 percent at that time.

2.13.6 Precision

The precision within laboratories: The average coefficient of variations within laboratories for products that expanded by greater than 0.1 percent on average during 14 days was found to be 2.94 percent. Consequently, two correctly performed test results on aggregate sample specimens in the same laboratory cannot differ by more than 8.3% of the mean expansion.

Multi laboratory precision: The average multi-laboratory variance coefficient for material that expanded by greater than 0.1 percent on average during 14 days was found to be 15.2% multi-laboratory precision. The effects of two well-conceived experiments on specimens of an aggregate sample in separate laboratories should not, therefore, vary by more than 43% of the mean expansion.

2.13.7 Expansion Limits

Expansions of less than 0.10 percent 16 days after casting indicate that the behavior is usually harmless.

Expansions greater than 0.20 percent 16 days after casting can be a sign of deleterious development.

The 0.10 to 0.20 percent expansions in the 16 days following casting provide both non-deleterious and deleterious aggregates in field quality. In such a scenario, comparator reading can also be helpful for 28 days [15].

2.14 Uranyl Acetate Gel Fluorescence Test

2.14.1 Scope

A new technique has been introduced for identifying ASR substances in situ [16]. ASR concrete substances were proposed as gelatinous silica and crystalline modifications with adsorbed sodium, potassium, and calcium ions. There have been considerable numbers of cations used to replace adsorbed silicone gels Na +, K +, and Ca ++. For its usual fluorescence under ultraviolet light, the uranyl (UO_2++) ion was picked.

Uranyl acetate solution has been used to treat specimens, and once correctly conditioned, ultraviolet light was seen under a short wave in a darkened region. The distinct greenish-yellow fluorescence of the uranyl ion indicated the existence of gel.

2.14.2 Materials and Methods

The mortar bars used in this analysis have been made according to the ASTM C227 expansion test. The bars were made of Na_2O equivalent cement of 0.95%. There was 20% opal found in the bars on the No.8 sieve, and crushed limestone was the harmless aggregate. In 45 days, the bars were split, with an average growth of 0.15 percent. Two mortar bars were made from four regular, 25mm x 25mm (1 in x 1 in) thin segments of petrography. Three thin segments were used during polishing and used for petrographic and quantitative tests. These segments were initially examined using polarized and crossed arrangements under transmitted light. There was a simple identification of opal particles and the existence of ASR gel.

The thin segments were washed and allowed to dry in $C_4H_6O_6U$ at 60 seconds. The areas of ASR products previously established had then been tested in UV light as later defined, and some special problems were noticed in the image of the fluorescence of thin segments treated by $C_4H_6O_6U$. The ion has a strong fluorescence when a shortwave of ultraviolet radiation (1800-2800 A) is excited by the uranyl ion.

The petrographic microscope was first examined to locate ASR substances and then the electron microscope to evaluate the compositions of the ASR substances. The thin segment was treated by $C_4H_6O_6U$, and fluorescence was noticed with petrographic microprobe and UV light. In an electron microprobe study, a Joel Superprobe 733, used primarily in wavelength dispersion (WDS), was used.

2.14.3 Outcomes

Analytical Petrography: Petrography evaluated the classical features of a well-developed ASR. Opal particles 'A' were identified by the 'B' rims and crack 'C' by the white gelatin materials.

The crack 'C' was observed under UV after treatment with uranyl acetate and shown an area significantly less displaced than the area. A comparison reveals that only ASR products are vividly fluorescent. The stem can be located in the minor crack 'D' to the left of the huge crack, which cannot be easily discerned, which also identifies ASR products. It should be noted here that the UO_2++ fluoresces with a distinctive greenish-yellow shade, but the original color pictures are only replicated in black and white. The opal 'A' particle found under UV light, After the comparison, reveals that the stain highlights ASR 'E' products which are not simple in the usual light around the opal particle.

Furthermore, the discolored 'B' rim of the central opal particle does not reflect the brightest fluorescent region. In a nutshell, the petrographic review concludes that staining is a susceptible tool for identifying alkaline-silica-reaction materials. The petrographic evidence seems to support the theory that the staining technique is only used to distinguish the ASR gel products (see Figure 2.4).

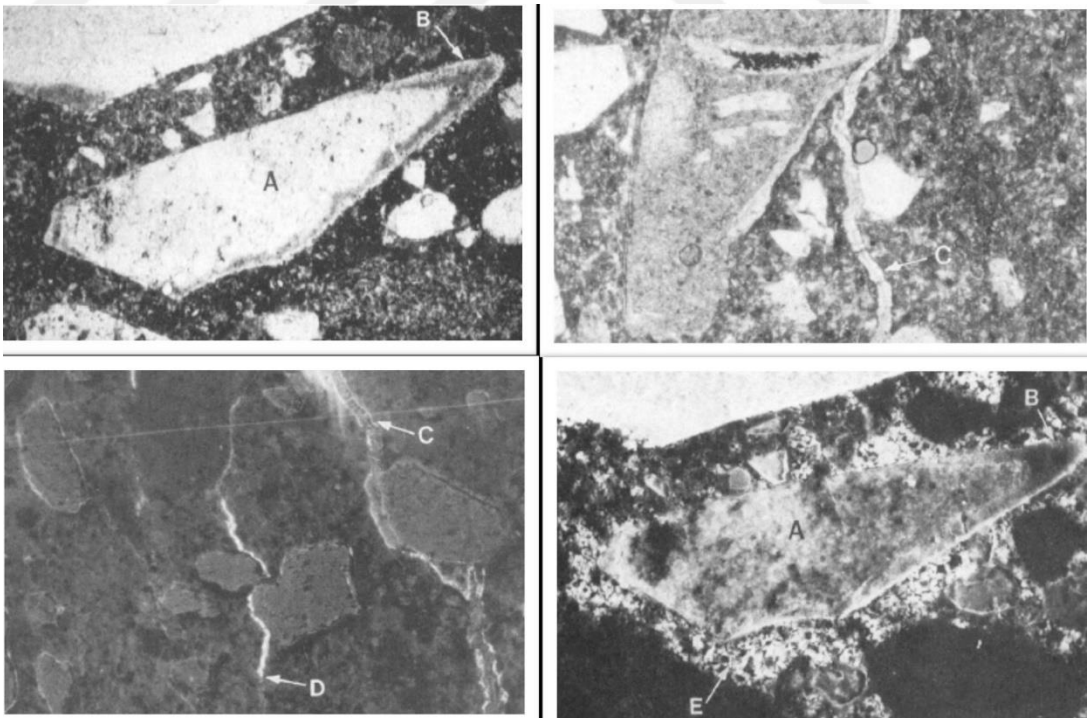


Figure 2.4 Display the petrographic analysis (by Kumar C. Natesaiyer and Kenneth C. Hover, See reference [16])

Microprobe Quantitative Analyzes: showed a standard reacted opal particle 'F' in the microscope under natural light. The particle has responded almost entirely, centrally positioned on the photograph, and the lower part, labeled 'G' Object, is shown.

The gel 'H,' with corresponding drying cracks is found to be large and isotropic. Compositional studies have been performed from a clearly defined point in the concrete paste, through the gel '1' through the reaction rim '2' and into the opal particle '3.' (See Figure 2.5).

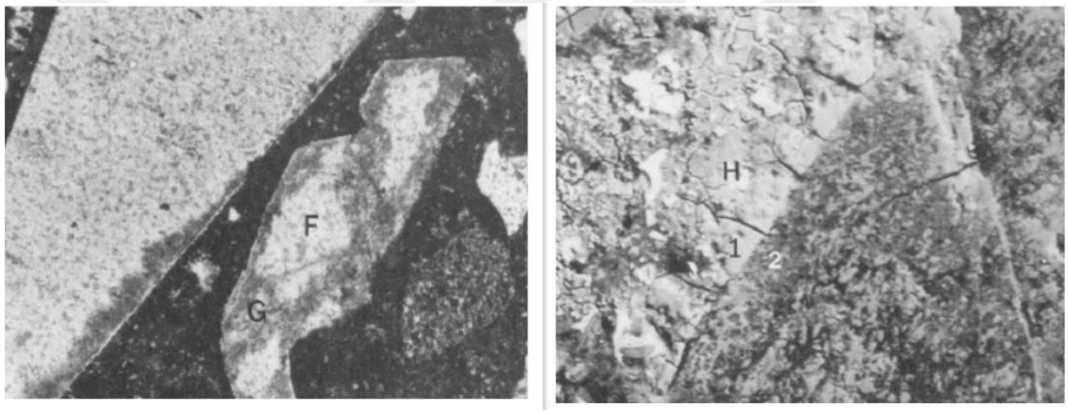


Figure 2.5 Show Microprobe quantitative analyzes (by Kumar C. Natesaiyer and Kenneth C. Hover, See reference [16])

After treatment by $C_4H_6O_6U$, the luminous fluorescent objects are again observed beside the paste, although the discolored border itself is only slightly fluorescent. Following treatment by $C_4H_6O_6U$ indicates significant texture shifts, and the area surrounding the particle appears to have been grafted by uranyl acetate. The X-ray map of the uranium element Noted major decreases to the gel/de-color rim interface in the uranium concentration. Only jelly substances and not the modified substance at the edge, or the opal fragment may have heavy adsorbed by the uranyl acetate [16].

Table 2.2 Electron Microprobe Analysis Results (by Kumar C. Natesaiyer and Kenneth C. Hover, See reference [16])

Oxide	Percent Composition by Weight			
	Cement Matrix	Gel	Discolored Rim	**Opal**
SiO2	20.55	65.72	83.84	89.48
CaO	37.24	15.32	4.85	0.14
K2O	0	4.3	2.64	0.16
Na2O	0	0.38	0.31	0
Al2O3	1.18	0.48	0.6	0.31
FeO	0.82	0	0.18	0
Balance	40.21	13.81	7.59	9.91

2.15 ASR Simple Chemical Test

2.15.1 Scope

The suggested method [17] includes the suspension of a CaO mixture and the aggregate to be evaluated in an alkaline solution, preferably KCl, held at 70 °C. The suspension is refreshed, filtered, and weighed after 24 hours, the filter's OH-ion concentration. In contrast with quartz sand and CaO combination regulation suspension, the OH ion concentration is then treated in the same manner. The difference between test and control in OH- ion concentration is an indicator of the ASR of the measured aggregate. It is worth noting that this test never reaches the cement paste ion concentration and research could be conducted on the ground and used to monitor the aggregate output. Latest reports indicate that, in accelerated test, that Na+ ions of NaCl and OH- of $Ca(OH)_2$ ions are added to reactive granules leaving Ca++ or Cl- ions of the liquid stage with NaCl ions. During the reaction, $CaCI_2$ is created in the liquid state. The aggregate's reactivity determines the $CaCI_2$ concentration. This new $CaCI_2$ would also decrease This new $CaCI_2$ also would decrease $Ca(OH)_2$ solubility by the typical ionic effect, i.e., depressed OH-ion, [Ca]/[OH] being higher than $Ca(OH)_2$ solution. The alkaline silica reactivity of the unit could be determined by keeping the unit at high temperatures (e.g.,70 °C) and by

measurement of its ion concentration in a $Ca(OH)_2$ suspension in the saturated alkaline chlorine solution, as well as by comparison to a quartz unit control suspension. The suggested testing of ASR instead of a saturated NaCl solution would also be rational.

2.15.2 Experimental Methodology

In this method, a sample of pure quartz sand and two reactive sands were used. Kallerup has more reactivity than CN sand of the other reactive types. For the making of suspensions, A newly burnished CaO sample and KCI (in room temperature) saturated solution has been used. A 120 ml KCI solution and 3.5 g CaO are mixed in a pyrex glass tube. The tube was tightly stopped and packed in a 70 °C oven. The oven was also fitted with 60 g of sand. In the KCl-$Ca(OH)_2$ solution, sand was added and thoroughly combined the next morning. The tube was stopped firmly and substituted on the floor. The tubes were suspended at 2-hour intervals for the first 8 hours. In a water bath and after 24 hours, the tubes were deposited for at least 3 hours at 20 °C; the contents of every tube were suspended at intervals during this cooling time.

A 0.45 µm membrane filter was used to filter the liquid stage of each suction tube. The OH-ion concentration of the filter is determined using phenolphthalein as the indicator by titration to a solution with a 0.025 N HCI.

$Ca(OH)_2$ solubility was determined in the Saturated KCI solution. Treat a 120 ml and 3.5 g CaO mixture precisely.

2.15.3 Results and Discussion

The concentrations of OH- ions are mentioned in Table 2.3. As shown in Table 2.3, the suspension involving quartz sand contains the same amount of OH- ion as the suspension devoid of sand. Table 2.3 also shows that the reactive sand suspension has smaller OH-ions than another suspension and lower OH-ion levels with greater suspended sand responsiveness. Table 2.3 also shows a decrease in OH-ion concentration. Reducing the concentration in OH ion in Kallerup- and CN-sand suspensions consistent with the previously suggested alkali-silica mechanism. Three more sand groups are being used to manufacture suspensions during the initial stages of developing the technique; however, suspensions were held at 50 °C for 21 days,

and OH- ion levels are assessed at periods of the 3 groups of sand, No.1 had been more sensitive while No.3 had been the least.

Table 2.3 OH- ion held at a temperature 70 °C (by Chatterji, See reference [17])

Sand Type	[OH-] in mg/l	Δ[OH-]
---	550	---
Vorvadsbro	547	3
CN	507	43
Kallerup	408	142

Table 2.4 displays the effects of this series. The suspension with No can be seen in Table 2.4 has the lowest concentration of OH- ion, and sand No.3 has the maximum concentration.

Table 2.4 OH- ion held at a temperature 50 °C (by Chatterji, See reference [17])

Time in days	[OH-] in mg/l		
	No.1	No.2	No.3
3	393	459	493
7	354	466	514
21	342	430	486

Both series results show that the KCl-$Ca(OH)_2$-sand suspension's OH- ion amount is inversely related to the sand's reactivity. This technique would then form a basis for a fast and easy procedure to determine the ASR of concrete aggregates if this finding could be repeated with other workers. One benefit of this technique is that no special equipment is needed and can be performed in an aggregate quarry by a technician for quality control. An aggregate may compare the decrease in OH-ion levels with the expansion of concrete induced, and a criterion of acceptance may be drawn. These possibilities are being evaluated further [17].

2.16 A New Designed Short-Term Test (SCPT)

2.16.1 Scope

Alkan Hafci [3] proposed this method as a part of his Ph.D. study. The scope is split into; comprehensive initial and final experimental trials. Steps of the initial experimental trial are (a) selection of aggregates, (b) preparation of soaking solutions with content change and (c) implementation of standard methods; AMBT and CPT and MABT, (d) To achieve study objectives, apply newly developed test methods to these aggregates. In the preliminary test analysis, 5 types of sandstones with the highest alkaline cement type, one kind of Ceyhan Basin sandstone, one kind of Izmir granite, and one kind of Coruh sandstone have been studied. Testing was carried out. "RILEM AC-219" and "RILEM AAR-4.1" as well as modified AMBT (at 60 °C). The results of the newly developed test methods were used for monitoring.

These new methods were made using a soaking solution with different ratios such as NaOH and chloride de-icing agents, pressed prisms (50 mm x 50 mm x 200 mm), and an adjusted aggregate Size distribution of a certain size interval of the obtainable tests. Various soaking solutions made for the most appropriate test method were developed for preliminary experimental studies to have excellent correlation with standard test methods and aggregates field results as follows:

(a) 0.3N NaOH + 1% NaCl + 1% $CaCl_2$, (b) 0.3N NaOH + 2% NaCl

(c) 0.3N NaOH + 2% $CaCl_2$, (d) 0. 3N NaOH + 2% $MgCl_2$

(e) 0.35N NaOH + 1% $CaCl_2$, (f) 0.35N NaOH + 2% $CaCl_2$

In addition, some types of aggregates carried out petrographic and mineralogical evaluations to detect the effect of these properties on possible alkalis. Finally, an observational investigation has been started to analyze the actual concrete structures prepared for their success in the field using test aggregates so that the reliability of the new method can be further monitored. The samples are given below with their numbers and measurements prepared for this experimental study:

1- MABT and AMBT: 120 mortar bars, 25mm x 25mm x 285mm.

2- CPT: 96 concrete prisms, 75mm x 75mm x 300 mm.

3- for newly designed methods: 252 concrete prisms, 50mm x 50mm x 200mm.

2.16.2 Research Significance

This new method tells that the test will be done in 28 days in a much shorter time compared to the 20-week CPT method, unlike AMBT Method, Severe aggregate crushing and handling, and test alkaline liquefaction. Samples typically found by CPT procedures can be observed. A comparative analysis by 32 aggregated styles has shown that the findings of the 28 days of the expansion of the new system have a strong level of association with the results of the CPT method during 20 weeks. These findings deduce the feasibility of the new approach to evaluate AAR as an alternative and reliable method.

2.16.3 Materials

Aggregate: A preliminary experimental analysis was performed on eight identified aggregate types and likely reactive and suspect. Initially, seven new test aggregates were created, and the best methods were selected based on their similarity to standard tests. The second step of the experimental analysis began with improving the selected methods necessary to achieve a better correlation. Finally, the previous experimental study was tested to complete the study with two new methods for 24 additional forms of aggregates (32 in total).

Cement: In the manufacture of mortar rods or concrete prisms, two cement I 42.5 R types were used, which by the associated standards "ASTM C150 or TS EN 197-1" are defined. In this experimental trial, test methods with related RILEM requirements are based on Na_2O_{eq} = 0.9-1.3 percent of the alkali equivalent; therefore, cement types were selected according to this requirement.

Sodium Hydroxide (NaOH): The most common chemical element used in a solution is sodium hydroxide (NaOH). Per the AAR test requirements, it offers alkaline concrete material to achieve up to 1.25 percent Na_2O_e. Only a guideline that NaOH should not be less than 98% pure is defined in the technical sentences.

Chloride Based Deicers (Salts): There are 3 types (1) Sodium Chloride NaCl (2) Calcium Chloride $CaCl_2$ (3) Magnesium chloride $MgCl_2$.

2.16.4 Test Methods

The methods for evaluating the possible alkaline reactivity of the aggregates for new methods for the reliability of the results were carried out with the "RILEM AAR-2 " (AMBT) and the "RILEM AAR-4.1 "(CPT).

AMBT and CPT test procedures are listed below:

"RILEM AAR-2 AMBT": is designed to determine unique AAR aggregates quickly. Due to a limited period of 14 days, the use of this approach is Fine supplemental mortars are cast into 25mm x 25mm x 285mm mortar bars (Figure 2.6).



Figure 2.6 Mortar Bars (by Alkan Hafci study, See reference [3])

After the mold removal, measurements of the longitude of ready samples are recorded as their first length, the samples are cured at 80 °C for one day in the water and weighed with a tape line in duration. The samples are then stored for 14 days in a sealed container to 1N NaOH at 80 °C in a soaking solution, and the length measurements by automatic comparators as shown in figure 2.7 are made (a).

The expansion percentages of the samples are determined according to the 14-day measurements of the form (L_{14}); 100x (L_{14}- L_0) / L. This approach defines the expansion limit of 0.2% for the determination of aggregate reactivity. In addition, aggregates with an expansion of 0.1% to 0.2% for AAR formation are accepted as hazardous materials.

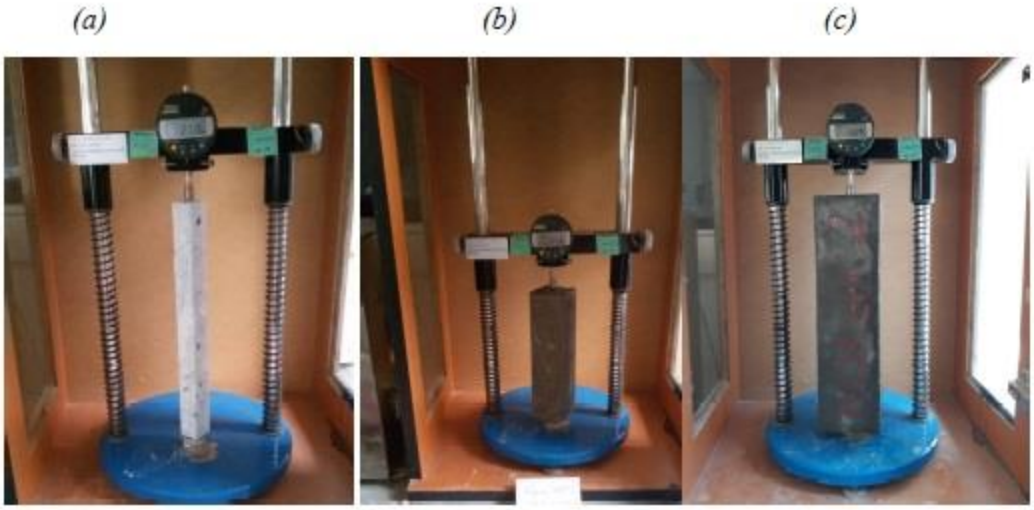


Figure 2.7 Length measurement of the specimens (by Alkan Hafci study, See reference [3])

"RILEM AAR-4.1 CPT": The accelerated CPT only takes a 20-week process while the long-term CPT ASTM C1293 lasts 1 or 2 years. It is achieved by measuring the length with a tapeline and registering it as L_0. The samples are then stored in a sealed container in a soaking solution of 1N NaOH at 80 °C in 14 days. The digital comparator calculates the duration shown above, which is used in Figure 2.7 (a). The percentage expansion rates of the samples are determined according to 14-day measurements of the form (L_{14}); ((L_{14}-L_0) / L_0) x100. This approach defines the expansion limit of 0.2% to determine the aggregate reactivity.

2.16.5 General Principles of the New Methods

Many complex solutions and cement shapes have been tested with modern methodological tests and changing storage temperature. This study explored in depth the principles of the new method development and the entire experimental study for creating a new method.

2.16.5.1 Test Specimens Mix Style

For, e.g., 28.6% of the fine aggregate, 42.9% of the coarse aggregate, 19.0% of cement, and 9.5% of water are content ratios prepared in the new system samples.

Consequently, a 1 m^3 concrete consists of 1658 g, 440 grams cement, and 220 g water (746 g fine, 912 coarse). It is also the product of these dimensions.

2.16.5.2 Size Distribution of Aggregates

In contrast to the standard RILEM AAR-4 CPT method, the maximum size of the device was 16 mm (22.4 mm). Investigators have shown that reducing the average total size from 22.4 to 16 mm does not correspond to the size of surfaces exposed to other sand particle reactions. Moreover, 45% fine aggregates and 55% coarse aggregates were also adjusted rather than as 60% coarse and 40% fine, as well as decreased the overall size of the aggregates. On the other hand, due to changes in the maximum dimension, the cumulative mass proportion of 16 mm must be 100. The main goal of these changes is to improve the functioning of the concrete mixture, making the process more realistic and simpler to produce test specimens in laboratory conditions than the conventional CPT system.

2.16.5.3 Exposure Conditions

Six new soak solutions have been produced for preliminary experimental testing to solve alkali leaching of 50mm x 50mm x 200mm prisms. 7 new approaches have been employed in this experimental item on eight aggregate forms. The findings compared to conventional AMBT and CPT methods using different ratios of NaOH and chloride-based deicers. Two additional methods have been developed in addition to these seven new methods. A way has been made to ensure that this preliminary aggregate (Gi) and 24 new types of aggregates are closely connected with the CPT test results (NGi). All the research specimens ready for implementing a new method were put into a sealed container to prevent alkaline leaching by concrete prisms and for 60 °C storage (Figure 2.8).



Figure 2.8 Specimens of a new method (by Alkan Hafci study, See reference [3])

2.16.5.4 Test Temperature

In the accelerated mortar bar experiments, 80 °C temperature is usually used during the reaction speed process. Several experiments have shown that such high temperatures are not real environments, thereby generating false positive/negative outcomes. The temperature in nature cannot be observed at 60 °C, because the concrete structure can be exposed to the temperature in some places. The temperature at a maximum of 60 °C will accelerate the reaction to a reasonable degree to complete the AAR test in a reasonable period. Many studies have shown that this temperature does not affect hydration efficiency. At 60 °C, on the contrary, it produces unstable phases of pore sulfur aluminum solution and excess sulfate. In short, this temperature gives a short duration of testing without disrupting the primary process of reaction and the concrete mixture products.

2.16.5.5 Test Specimen Size

The reasons are the collection of thin concrete prisms 50mm x 50mm x 200mm to prepare test specimens.

(a) Test specimen preparation is more functional than the CPT standard.

(b) It should be made more accessible to enter the narrow concrete prism with pins, as the conformity calculation is generally applied by TS EN 1367-4 dry-shrinkage assessments to the Turkish standard "TS 706 EN 12620- Concrete Aggregates."

The research's similarity with the CPT method can be more plausible

(c) all of the concrete prisms evaluated are 1.5 times less than in the standard CPT method.

2.16.6 Conclusions of SCPT

The following conclusions may be drawn in light of the findings of SCPT experimental research:

(1) At first, SCPT takes 28 days in contrast to long-term CPT. Secondly, AMBT exposure was reduced to 1% $CaCl_2$ instead of 1N NaOH by 0.35N NaOH+, and the temperature of storage was reduced from 80 °C to 60 °C. Thirdly, using narrow concrete prisms 50mm x 50mm x 200mm instead of 75mm x 75mm x 300mm. Fourthly, the coarse aggregate 16mm scale increases concrete workability rather than 22.4 mm. Finally, SCPT tests both finer and coarse aggregates together.

(2) In the measurement of test aggregate reactivity, SCPT data show excellent consistency with the CPT data. The rate of expansion (0.04%) may be acceptable in the standard error margin due to the insecurity of measurements of experimental studies. The new approach (SCPT) thus eliminated one weakness of the test methods available.

(3) The study of regression to assess the degree of association between AMBT and CPT association demonstrates that association is not strong. It may be attributed to false positive/negative expansion effects from AMBT because of this incompatibility. Due to excessive test conditions, the short-term test for 14 days may yield unreliable results. However, if false negative/positive AMBT results are derived from the comparison study, the AMBT approach may give a strong CPT correlation. It shows that AMBT's greatest drawback is false negative/positive findings. For all outcomes of the test, except for false negative / positive results extracted, SCPT provides a stronger correlation with AMBT than CPT.

(4) The most powerful chloride-based deicers in alkaline combinations of the concrete reaction have been sodium chloride (NaCl) due to the acceleration of the reaction. Samples of concrete prisms exposed to calcium chloride ($CaCl_2$) soak solution rather than NaCl have less expansion than NaCl deicer. In addition, magnesium chloride

($MgCl_2$) is not as essential as other chlorides as contributing to the alkaline aggregate reaction.

(5) The concrete prism samples subjected to the newly established method undergo a dramatic expansion in sodium hydroxide (NaOH) and $CaCl_2$ following particularly 14 days. Because of the AAR expansion process, $CaCl_2$ should therefore be studied in depth.

(6) According to the findings from the experimental analysis, petrographic and mineralogical proprieties of aggregates tend to affect the possible reactivity of alkalis even if they cannot give exact results. Additional checks should also be carried out to assess the aggregate reactivity before being used in a concrete structure.

(7) The cement form with higher alkaline content improves expansion, compared with two different cement forms with different alkaline content. Regression analysis comparing expansion rates in samples tested with DNM2 and PNM6 was performed in this experimental study. A formula to determine the effect of cement style on the rate of expansion of lab test aggregates called Gi was developed, taking the equivalent sodium oxide from cement into account.

$$Y=1.26\Phi_{eq}X \quad \textbf{(2.5)}$$

where;

Y, X= expansion (%)

Φ_{eq}= the ratio of equivalent sodium oxide = Y (Na_2O_{eq})/ X (Na_2O_{eq}).

(8) Except for water absorption (WA_{24}), no other variable of the test aggregates' mechanical or physical properties is shown to have an apparent effect on AAR expansion. Due to its porosity ratio, which affects the aggregates' resistance to a chemical reaction, water absorption may be viewed as one potential factor that affects the AAR process.

(9) likely, they would not be perfectly compatible due to a lack of knowledge about the constituents of current concretes and varying climatic factors (relative humidity, temperature). Given visual manifestations produced by the AAR on existing concrete structures, SCPT provides generally consistent results with the field performance of aggregates.

2.16.7 Limitations

The principal objective of this experimental analysis is to solve the shortcomings of traditional AAR research methods. SCPT architecture can be seen as mitigating these disadvantages. Nevertheless, SCPT has the following limitations:

1) $CaCl_2$ is the primary component of the SCPT soak solution., can react to certain components and produce unexpected products because of the unclear elements of the role of calcium in the AAR mechanism. Detailed petrographic analysis of aggregates and the conduct of the components of such aggregates may be necessary when exposed to calcium.

2) SCPT is a form of accelerated testing that differs from standard CPT testing in that the test conditions are increased. Concrete prism specimens such as aggregates will expand slowly enough that their expansion during the 28-day testing period is undetectable. It is why SCPT can provide false results [3].

CHAPTER 3

LITERATURE REVIEW

In this chapter of the thesis, a comprehensive literature review of past research studies on alkali-silica reaction in concrete will be presented, and a brief synopsis and test criteria for each study will be given.

3.1 Predictability of Aggregates Improved by ASR Study

In the paper by William J. Heck [18], Chemical ASTM C289 and Petrographic ASTM C295 tests on concrete aggregations were carried out in natural silicate and artificial calcareous sands. The evaluation was performed on ASTM Tests for potential chemical aggregate reactivity tests C289. None of the test methods considered in the research study alone was able to estimate the potential for ASR; The chemical test was not corresponding correctly with the mortar-maximum bar's expansion at six months of age, suggesting reactive aggregate.

The test results indicate that with an expansion limit of 0.1% to six months, the potential reactive material is not adequately specified. The maximum expansion limit should be reduced by 6 months to 0.075%. It is proposed, due to the grading effect and the expanding variability, the substitution of the mortar bar test with a CPT should be considered.

The calcareous aggregate tends to influence the reactivity of alkali-silica, so adding calcareous aggregates can be a practical method of making them functional in concrete.

According to the findings of this experiment, the correlation between rapid chemical tests and mortar-bar test data is not entirely trustworthy. All of the sets surpassed the three-month limit (0.05 percent expansion), which is consistent with the chemical test results, whereas none of the sets of bars exceeded the six-month limit of 0.1 percent, and only two sets did so during one year, indicating a rather low association. When a limit of expansion of 0.075 percent was used at six months of age, seven of the nine sets of bars are considered reactive, correlating well with the fast chemical test for the

siliceous aggregate examined here. The author proved that there is no correlation between the rapid chemical test and the mortar-bar test for aggregates including limestone due to the inhibitory effect of relatively high concentrations of limestone on alkali-silica expansion; and that the relation between the chemical and mortar-bar tests was lost when siliceous aggregates contain a greater fraction of reactive elements than the permissible amount, additionally, the issue of poor correlation between the chemical and mortar-bar tests is generally due to the mortar bars' expansion unpredictability. It is noted that when the deviation and variance of mortar-bar expansion are compared to the sand grading or the amount of reactive material, no consistent pattern emerges. However, changing the test technique in this manner may not be practicable. Rather than that, it is advised that a concrete prism test be constructed.

3.2 Comparative Study of Field and Lab Results on Concrete on ASR

In this article written by Nancy M. Whiting [19], The sand measured has a potentially deleterious expansion in the Mortar Bar ASTM C1260 (expansion 0.2%), but not detrimentally in the ASTM C1293 test (0.0295 to 0.042 percent expansions). Even though these C1293 prisms remained thin, there was a response to gel, spalls, and cracks in the form of sandy opaline shales. Similar cracking and gel formations have been observed in field samples of these shales. The quartzite mortar bars of C1260 were moderate to expand, and the prisms of C1293 were larger than the 0.04 percent maximum expansion. ASTM C1260 showed an average expansion of 0.135 to 0.188 percent with crushed quartzite, while C1293 showed 0.082 to 0.1137 percent expansion with coarse quartzite exceeding the maximum expansion limit of 0.04. Quartzite reacts on many floors but is not as widespread as the high results of the C1293 tests suggest. The sands react in pavements and test samples, but this reaction does not manifest in the C1293 prisms.

In this article, all twelve concrete pavements were evaluated and deteriorated prematurely as a result of ASR. By reviewing the study's findings, they were found that in all pavements, the presence of opaline shale in the fine aggregate contributes

to their failure. It was observed Laboratory mortar and concrete specimens prepared from the same sand demonstrated two distinct behaviors: the C1260 in these pavements exhibited the potential for excessive expansion, while the C1293 did not exhibit excessive expansion, but laboratory specimens exhibited similar symptoms to field concrete, including cracks, gel, and spalling concrete associated with reacted shale particles.

Also, it was noticed that when using crushed quartzite, the laboratory mortar specimens prepared from it for the C1260 test failed the test or expanded excessively, resulting in inconclusive results. In contrast, the C1293 test conclusively indicated that the quartzite possessed the potential for deleterious expansion exceedingly twice the recommended expansion limit.

From the above mentioned, it can say that the expansion of C1260 specimens was a good predictor of field performance for the six sand sources investigated but was insufficient to determine the ASR potential of the quartzite, and on the contrary, expansion of C1293 prisms was a good indicator of ASR potential in field concrete for quartzite, but not for the sands studied.

3.3 A Comparative Study Between RTA T363 and ASTM C1260 Methods to Detect Reactive Aggregates

This research conducted by Ahmad Shayan and Howard Morris [20], aims to compare, using several aggregates with known field efficiency, the expansion data achieved using the two test methods and evaluating the validity of the expansion constraints in determining these aggregates' field efficiency. A comparison of two methods for determining the efficacy of fly ash in inhibiting AAR expansion is also covered in the research. The RTA limits are suggested for determining the sufficiency of the fly ash used in expansion control. The results of the two methods' accelerated experiments can be classified into two categories: those in which the RTA T363 method performed better than the ASTM C1260 method and those in which the two methods performed similarly. The increased expansion in the ASTM C1260 is due to the method's high

water/cement ratio of 0.47 (values about 0.40-0.42 in the RTA T363 method), resulting in increased porosity NaOH processing solution better access to the aggregate.

After reviewing this study's results of the accelerated tests, we found them indicate that the reactive aggregates in ASTM C1260 display greater expansions than in the RTA T363, although nonreactive or slightly reactive aggregates demonstrate nearly similar expansions in both methods. The increased expansion in ASTM C1260 is due to the high w/c ratio of 0.47 compared with 0.40 ± 0.42 of the RTA T363 method, which findings in increased porosity and provides the NaOH storage solution easier access to the aggregate. Also, it is observed that both methods categorize Excel sand as nonreactive, but the two TMC aggregates are classified as reactive. According to the RTA T363, both French coarse and fine aggregates are slowly reactive, whereas the ASTM C1260 limit placed them in the doubtful area.

BGT and CNN aggregates have been classified as slightly reactive according to the RTA technique provided that 10-day expansion values are less than 0.1 percent and their 21-day expansion values are larger than 0.1 percent, while ASTM standard characterizes these aggregates, as non-reactive due to their modest 14-day expansion (0.1 percent). Nonmandatory data in the ASTM C1260 appendix states that certain reactive granitic rocks may exhibit expansions of less than 0.1 percent 16 days after casting (14 days immersion). The usage of RTA limitations benefits these aggregates. When using fly ash, it was observed the results of mentioned test techniques provided nearly similar results, demonstrating the efficacy of fly ash in limiting AAR expansion. The ASTM test limit of 14 days classifies the mixture as non-expansive, while the RTA test limit of 0.1 percent expansion after 21 days classifies the mixture as slightly reactive.

Furthermore, it is found from this study's results that both procedures revealed cracking in the mortar bars comprising Japanese aggregate and 25% fly ash. This corroborates the RTA T363 conclusion that a 25% fly ash replacement rate was insufficient to prevent AAR expansion. As a result, the RTA T363 limitations are deemed to be more adequate for estimating the effectiveness of fly ash in inhibiting AAR expansion in highly reactive aggregates.

3.4 Checking of Recycled Concrete Using Accelerated ASR Test

This study by D.L. Gress, R.L. Kozikowski, and T.T. Eighmy [21], concentrates on investigative techniques and techniques for assessing the expansion capacity of ASR for concrete composed of recycled concrete aggregate (RCA), considered to be ASR-containing or to be capable of exhibiting ASR in increased alkali conditions. It has been demonstrated to accelerate ASR and reduce the variance of expansion data, with standard prisms of 280 mm with 76.2 mm faces installed at four 6.35 mm parallel length holes. Compared with the regular prism, the expansion of concrete cubes of 76.2 mm is considerably accelerated. In evac bags, water-bonded prisms were discovered to speed up the ASR expansion significantly. Concrete prisms have been subject to ASTM C1260 and ASTM C1293, and findings for modified microwave tests have been compared.

In this study, the expansions of the samples with holes were approximately 65 percent more than those of the solid samples and 33 percent greater than those of the cut samples after 21 days According to ASTM C1260. The standard test for the WY aggregate expanded by 14 days (0.21 percent) in approximately 100 days. In 21 days, the samples with holes expanded by approximately 1/3 of the usual 14-day rate. Comparing the 28-day expansions of the RCA and WY aggregates reveals that the RCA concrete expands at around 89 percent of the rate of the solid samples. The enhanced rate of growth of prisms with holes indicates that the mechanism of expansion is greatly influenced by diffusion processes. The holes in the prisms increase the surface area available for diffusion and also shorten the diffusion channel lengths, accelerating the process.

As was the case with ASTM C1260 testing, at early ages, the cube samples expanded almost three times faster than the solid samples. The expansions were between 21% and 63% more than those seen in the conventional test. When compared to the bigger prisms, the cubes with holes demonstrated significantly rapid expansions of more than a factor of two after 21 days. The solid sealed samples demonstrated the least mass gain for a given expansion, which was in direct contrast to the usual ASTM C1293 test data.

As the case with the other ASTM C1293 tests, small cubes exhibit greater expansion than bigger prisms. Expansions were often slightly greater than those measured in sealed ASTM C1293 testing. The holes in the samples demonstrate a greater mass gain than the solid samples. Comparing microwave cubes to sealed cubes in ASTM C1293 indicates that the microwave has a negligible influence on expansion, this could be a result of the microwaves' drying effect on the smaller samples with holes.

3.5 Predicting ASR Using ASTM C1293, C1260, and Their Updates

This research was performed by Wissam E. Touma and others [22] and focused on the most important practices for minimizing harm by recognizing an aggregate's sensitivity to ASR before using it in concrete. ASTM C1260 and ASTM C1293 were used to distinguish ASR-susceptible aggregates. The modifications to ASTM C1260 consisted of conducting the test using various normalities of the NaOH solution, like (1,0.75,0.5, and 0.25 N). The improvements to ASTM C1293 involved raising the temperature from 38 to 60 degrees Celsius and holding the concrete prisms at 38 degrees Celsius in a 1N NaOH solution will efficiently boost to produce findings in 3 months rather than one year.

In this research, compared results ASTM C1260 and ASTM C1293 involved a comparison of 14-day expansions obtained by ASTM C1260 to 52-week expansions obtained by ASTM C1293. 14-day expansions of less than 0.10 percent were highly linked with 52-week expansions of less than 0.04 percent for harmless aggregates.

Also, slowly reactive aggregates with 14-day expansions of 0.10-0.20% were classified as such with 52-week expansions of 0.04-0.07%. However, petrographic investigation of these aggregates revealed no reactive components.

In addition, five of the eleven aggregates with 14-day growth rates greater than 0.20 percent had a strong correlation with 52-week expansion rates of more than 0.07 percent. These aggregates were reactive in the field and included reactive elements during the petrographic examination. The other aggregates did not conform to the previous data, exhibiting a variety of reactivities.

As indicated previously, ASTM C1260 should not be utilized in isolation but should be complemented by ASTM C1293. ASTM C1293, on the other hand, maybe utilized independently to forecast the AAR. The petrographic investigation of the slowly reactive aggregates examined revealed no reactive materials.

3.6 Suggested Autoclaving in Glass Aggregate Bound Composites for ASR Screening

This research was conducted by S. Kozlova and others [23] at Columbia University to determine the feasibility of using post-consumer waste glass as a concrete aggregate. A goal was to create less reactive mixtures and included glass, pozzolanic materials, and a combination of several admixtures. It is necessary to have many variables to identify undesirable components before unnecessary long-term testing. A new ASR test suitable for both conventional concrete mixtures and multi-component systems has been developed and find test results in three days. Using the proposed autoclave test, an essential component to mix design is reduced, allowing designers to focus on incorporating the perfect composition rather than possibly running into other competing compositional options. Additional long-term ASR tests are needed to evaluate promising compositions adequately.

Only when mixtures were resistant to the touch of a sodium hydroxide solution was there a correlation between the findings of the autoclave test and the ASTM C1260 test. When it comes to formulations of glass aggregate, the ASTM C1260 test does not seem very precise.

After the sodium hydroxide solution reaction, the pore solution changes, resulting in a decrease in expansion when the unwashed glass is used. The measurement extensions, while somewhat constrained, can produce conclusive results.

This paper explained that the suggested autoclave test takes approximately 14 days less time than the ASTM C1260 test and does not add an active component to the mixture. Since the autoclave test utilizes only water vapor, the role of non-alkali components in the concrete becomes critical. It's concluded that A 24-hour autoclaving period is adequate to produce unique patterns where certain mixtures

demonstrated anomalous expansions that may be approximately increased upon extra testing.

Further, the ASTM C1260 test assumed a limit value of 0.10 percent for reactive mortars, while the ASTM C1293 test proposed a limit value of 0.04 percent after one year, whereas the autoclave test's similarly small expansions preclude the recommendation of a precise limit for the identification of reactive mixtures.

Also, it is noted that the autoclave test takes measurements under constant conditions after the specimens have been carefully cooled, minimizing the effects of temperature, humidity, pressure, and time. The findings of this study support the utility of autoclave testing which enables the examination of concrete that comprises not only standard components such as water, cement, sand, and gravel, but also additives, pozzolans, or irregular aggregates. Modifications to current autoclave tests resulted in the development of a novel fast ASR test capable of establishing non-destructive test conditions for detecting possible ASR deterioration.

3.7 Test of ASR Using a Modified ASTM C1260

The research program by Chang-Seon Shon and others [24] included variations of alkaline cement formulas: some with Class C and F fly ash and others with neither. The findings indicate that, given nominal differences in alkali cement, the mortar samples' level and amount of expansion can be established under most experimental conditions. The expansion in fly ash bars is usually lower, but a 20-percent substitution of fly ash might not be ideal for w/c = 0.47 to lower expansion. Expansion in fly ash class F is decreased more than fly ash class C.

However, the expansion in w/c also was decreased with Class C fly ash = 0,47, as weights of cement increased to 35% in replacement amounts. If high alkaline cement at w/c = 0.47 is present, the fly-ash class C bars of the mortar containing 20% are usually not suitable. Interestingly, prolonged humid curing for 28 days raises the expansion level independent of the cement alkaline, and fly ash levels substituted.

As a result of this study, it is concluded that the expansion characteristics of plain cement mortars are determined by the normality of the alkali hydroxide solution.

Reduce the w/c from 0.47 to 0.35 and the expansion rate decreases little, while extended moist curing has even less effect. To determine the expansion of mortar bars with regularity of 0.25, the test must be conducted over a substantially longer length of time. Although aggregate expansion just meets the 'possibly reactive' requirement for aggregates at 14 days, between 14 and 28 days, a dramatic change in expansion characteristics occurs. At 28 days, expansion considerably exceeds the 'reactive' aggregate criteria. When the normality of the test solution is reduced to 0.5 N, however, expansion at 28 days remains close to 0.20 percent, which is considered the upper limit of expansion for 'potentially reactive' aggregate; expansion is marginally greater than 0.20 percent in the case of high-alkali cement, whereas it is marginally less than 0.20 percent in the case of low-alkali cement mortar.

The observation that most other mortar bars containing 20% classes F and C fly ash expand less than 0.10 percent after 14 days, but most expand more than 0.10 percent after 28 days, shows that the expansion tendency is fairly similar to that of plain cement mortar bars. This is to be expected, given the small amount of fly ash replaced. Interestingly, except for mortar bars containing 20% fly ash, the dependence of expansion on the normality of sodium hydroxide solution does not appear to be as essential as it is in plain cement mortar bars. Rather than that, the amount of fly ash replacement and w/c is more important. Unlike plain cement mortar bars, those incorporating fly ash that has been moist-cured for a long period of 28 days demonstrate greater expansion than counterpart bars that have been moist-cured for 24 hours according to the C1260 method. This observation is interesting in that it is indicative of the slower rate of microstructural development in fly ash concrete under normal field circumstances. It is self-evident that curing at a higher temperature increases the initial strength. However, plain cement concrete cured at 80 degrees Celsius produces a somewhat higher 3-day strength than concrete cured at room temperature. Although fly ash concretes have a lower early age strength than plain cement concretes, the relative rise in strength of concrete containing fly ash cured at an elevated temperature is greater than that of the corresponding plain cement concrete at this age.

3.8 ASR in Mortars Produced from Aggregates of Various Levels of Crystallinity

Ana Mladenovič and others carried out this research [25]. The characteristics of the reaction lines between each grain of such aggregates and the cement paste induced by ASR were assessed with mortar bars, including three various types of silica aggregates aged per ASTM C1260. The use was made of three silicone aggregates: crystal-based quartz, crystalline flint, and poorly crystalline diatomite. The morphology of the reaction rims was determined using SEM, and EDS determined its chemical composition. The number of Si-ions spread to the cement paste's direction and the number of Ca-ions and alkalis spreading to the silica aggregate were determined.

The flint-group resulted in a linear expansion of about 0.24% after 18 days of aging, while $CaO\text{-}SiO_2$- rich gel expanded about 0.56% of the diatomite-group expansion (no major expansion occurred in the presence of the quartz aggregate). In the presence of intermediate and poorly crystalline aggregates that may prevail over the effect of crystalline material in specific quantities in the amounts of concrete and mortar, it was found that alkaline silica reactions with crystalline reverse, though there has been a strong effect.

Based on the test findings, all aggregates studied exhibited ASR, which resulted in the formation of calcium-rich gels, i.e., lime-alkali-silica gels. The kind and degree of crystallinity of the silica aggregate did not affect the chemical composition of these gels. When the pessimum impact for flint and diatomite is examined, the estimated expansion of the mortar bars matches well to the crystallinity of the various silica aggregates as indicated by a CI-index. In the event of the quartz aggregate, no considerable expansion was seen. Also, in the scenario of the F+IA and D+IA mortar bars, the observed expansion can be clarified by the presence of large quantities of lime-alkali-silica gel and the style of microcracks in both the cement paste and the reactive aggregate particles, and occasionally in the inert aggregate particles, based on the intensity of the reaction. This means that examining the kind of cracks that form within experimental mortar bars may be extremely beneficial for predicting the long-term stability of mortars containing reactive aggregates. Furthermore, the distribution

of alkali SiO_2 and CaO along the lime-alkali-silica rim revealed that the largest concentration of Ca ions occurred in the reaction rim's center, with a decreasing tendency toward the silica aggregate. On the other side, the density of Na and K ions was only around 1 percent on average and was greatest at the point of access of the rim with the aggregate.

3.9 A Critical Evaluation for ASR Performance in Concrete

This article by Mohammad Shahidul Islam and Sazeda Akhtar [26] offers an overview of concrete alkali-silica reaction, discussing context, ASR dynamics, ASR influencing variables, and ASR indications. Using field results, stratigraphic analysis, aggregate geology, and the typical and updated ASTM C1260 and C1293 methods and their revisions, the aggregates that were subjected to ASR were evaluated. The research showed that no single method is an optimal methodology for assessing an aggregate's alkali-silica reactivity, and an effective mix of different techniques is used to predict an aggregate's possible ASR more accurately.

It is highly urged against using the aggregate form as the primary tool for determining aggregate reaction. Although pure dolomite and limestone minerals are considered harmless, alkali-silica reactions are susceptible to Andesite, Dolomitic-Limestone, Dacite, Rhyolite, Opal, Basalt, Pyrex Glass, Quartz, Chert, and Silica minerals. The alkali concentration of cement does not affect mortar bar expansion, and the restriction of cement alkalis less than 0.6 percent Na_2O_{eq} is not preventing ASR from falling below the prescribed expansion levels. However, mixing an adequate quantity of pozzolans in the concrete mixture like fly ash enhances concrete properties and decreases the harm associated with ASR.

What was observed in this study is that the 14-day expansion limit of mortar bars of 0.10 percent resulted in identical agreement on aggregate classifications as the aggregate mineralogy and the expansion limits of alkali-cured prisms at 4, 8, and 13 weeks, except for the rhyolite aggregate group. The ASTM C1260 recommended early age failure limit for mortar bars gave more conservative results than the Hooton (1991)

and Rogers and Hooton advised 14, 28, and 56-day expansion limitations for mortar bars (1993).

The concrete prism test demonstrated a strong connection with the petrographic results. It did not, however, demonstrate a high degree of agreement with the results provided by field performance and aggregate mineralogy. The expansion limits of alkali-cured concrete prisms at ages 4, 8, and 13 weeks did not match those determined using the usual concrete prism test.

Among the ASR evaluation tests, the aggregate mineralogy and early age expansion limit of mortar bar resulted in a more conservative approach, followed by the alkali-cured prisms' expansion limitations. In comparison to other test methods, the concrete prism test may provide the most accurate assessment of ASR since the specimens are more likely to be exposed to actual field conditions. On the other hand, the aggregates' ASR classifications based on field performance were not as planned.

3.10 Assessing ASR of Aggregate Using an Accelerated Autoclave Test

Eric R. Giannini and Kevin J. Folliard [27] produced a new rapid test using autoclaved concrete prism can be outlined in this article. The prisms used in ASTM C1293 are autoclaved for 24-hour to a 0.20 MPa saturated steam setting. The test lasts four days from the concrete mixing before the final expansion calculation. An expansion of 0.08 percent was proposed to classify not reactive and potentially reactive aggregates.

This study showed both ASTM C1260 and ASTM C1293, which classify aggregates as possibly reactive or non-reactive, correctly classify all aggregates in the first Phase, and the expansions of the autoclaved concrete prisms compare favorably to these tests. This is especially true when compared to ASTM C1293; the expansion of aggregate including (gravel, rhyolite, and other volcanic) in ASTM C1260 is astronomically high in comparison to ASTM C1293 and its well-documented field performance. Prisms autoclaved with (gravel, rhyolite, and other volcanic materials) expanded more similarly to prisms evaluated according to ASTM C1293. Additionally, the autoclaved CPT appears to have some intrinsic expansivity, even for confirmed non-reactive

aggregates. Although the reason for this is unknown, it does justify a recommended expansion limit of 0.08 percent.

Although the data set is insufficient for more thorough data analysis, the samples in the second phase demonstrated extremely low variance in each group of three samples. Within each group, variance can be quantified using a rough coefficient of variation (half of the range of expansions divided by the average expansion); this varied between 1.6 percent crushed greywacke and 8.6 percent Crushed granitic gneiss and were always lower than the maximum coefficient of variation of 10% suggested by Grattan-Bellew for a single carrier.

3.11 New Test for AAR in Iceland

By Sóley Unnur Einarsdóttir and Børge Johannes Wigum [28], four separate test methods were investigated in this project for Alkali Aggregate Reactions. Eight various Icelandic aggregates were used for each process, and 1 of 8 aggregates with 9 different combinations of cement and pozzolanas was tested in all four techniques. The findings indicate a comparatively higher expansion in the RILEM AAR–2 test than the other research procedures. The latest tests for concrete prisms by RILEM show the effects of aggregate forms, cement, and pozzolana. The ASTM C227 mortar bar test illustrates the effects of pozzolanas, but for mixes with low alkaline cement, the expansion is very low. Based on the results of this project, the new Icelandic Building Regulations are deemed appropriate.

For this research, the weight change results from the RILEM AAR-3 and AAR-4 tests indicate that Aggregate A, which shows a very significant weight gain in both tests, is a highly porous aggregate with a high-water absorption capacity. Water is probably being used to fill the spaces, which accounts for the significant weight gain. In addition, in RILEM AAR-3 and RILEM AAR-4, the H aggregate demonstrated a reasonably significant weight gain. Aggregate H is a very dense aggregate with a low water absorption value, and we have not been able to determine a rationale for the weight increase observed during testing.

Also, it is considered that adding silica fume to the mixture in the laboratory is insufficient since the silica fume is unlikely to be evenly distributed. Besides, ASTM C227, RILEM AAR-3, and RILEM AAR-4 tests demonstrate that the mix with the highest alkali cement and no added pozzolanas exhibit the greatest expansion. Further, the RILEM AAR-2 test states no discernible effect of reduced expansion with pozzolanas or low alkali concentration in the types of cement. The expansion factor for test samples that do not contain silica fume is set to 1.0, while the expansion factor for specimens that do include silica fume is computed as a proportion of the 1.0 expansion factor.

As a result of the mortar bars having unfettered access to alkalis during the test period, adding silica fume or utilizing low alkali cement has a negligible effect on the RILEM AAR-2 procedure. The addition of silica fume in the ASTM C227 method reduces the expansion by a factor of approximately 0.5; however, it is considered that this effect is exaggerated due to the influence of alkali leaching in this approach.

In the RILEM AAR-3 method, cement containing 6% silica fume reduces expansion much more than cement containing only 4% silica fume. This is regarded to be a more accurate reflection of the actual situation. In the RILEM AAR-4 method, the impact of cement containing silica fume results in a similar reduction in expansion as in the ASTM C227 method. However, comparing the ASTM C227 and RILEM AAR-3, the effects of low alkali cement result in a smaller decrease in expansion. It might be because the test period is relatively short (20 weeks), limiting the possibility of alkali leaching.

3.12 ASR Kinetic Approach: Comparative Study of Lab and Field Results

Laboratory studies of over 100 aggregates were performed by N. Gowripalan and Vute Sirivivatnanon [29] for long-term field results accessible on a global scale. Compared to the interpretation of AMBT results, A kinetic method for interpreting CPT findings is a relatively complicated process mainly because of significant changes in initiation

time (induction period). Analyzes are made using filament parameters to determine the ideal proportions of additional cemented substances needed to mitigate ASR mitigation. Johnston's kinetic approach can be easily used for AMBT, CPT, or other accelerated expansion research findings. This approach is currently being applied to ACPT, requiring a few iterations of different induction time values to apply the results to CPT. The test will also need to be performed for mixes with additional cemented substances for a longer time. The kinetic method based on expansion rate parameters may be defined as "reactive" and "non-reactive" (as opposed to the expansion itself at a given age), even with expansion steps for a shorter time.

ASTM's findings claim that AMBT only takes 14 days, but AS estimates that it takes 21 days. However, AMBT is overly reactive due to the harsh conditions under which it operates. On the other hand, it grossly underestimates the reactivity of some aggregation types. CPT, on the other hand, is a lengthy procedure and correlates favorably with field performance as compared to AMBT. CPT or accelerated CPT (ACPT) can be used to acquire kinetic parameters, and the same theory and equation apply to field measurements as well. On the other hand, ACPT allows for shorter test periods. Classification criteria for aggregates based on kinetic parameters require additional exploration.

3.13 Role of The Test Method in The Detection of Alkali-Silica Reactivity of Concrete Aggregates

Muhammad J. Munir and 4 researchers conducted this study [30]. The mineralogy of aggregates from five separate reservoirs has been studied in this study. For these aggregates, the mortar bar expansion was checked in compliance with ASTM C227 and C1260 Guidelines. Though the examined aggregate sources were found to be non-reactive under ASTM C227 test conditions, ASTM C1260 defined a possible aggregate category. The electron microscopy scanning imagery indicated that two aggregate sources were reactive. The strength reduction caused by the ASTM C1260 application was comparable to that caused by the ASTM C 227 application in samples

older than six months, as shown by compressive and flexural strength test results in older samples with reactive aggregates.

SEM imaging was used to capture microstructural features by measuring the expansion and deterioration of material characteristics. The gathered data will be from the experimental findings. The mortar expansion of ASTM C227 in the Sargodha area was from 0.05 to 0.07% for specimens incorporating aggregates. Specimens made from combined sources of Jhelum and Kamser showed a lower expansion of less than 0.04 percent, either because the impact was pessimum or because it was not reactive. A different approach has shown that all tested aggregate sources in the Sargodha area have been reactive with an increase of more than 0.20 percent using ASTM C 1260.

Compressive strength reductions ranged between 22 and 25% for samples tested according to ASTM C227 but were between 10% and 20% for samples tested according to ASTM C1260.

For Sargodha, aggregate sources checked by ASTM C227 with 23 to 29 percent decreasing flexural strength were observed. Related specimens under ASTM C1260 (ASTM, 2014c) have suffered from a bending strength reduction of 22 to 34%. The bending strength of samples with aggregate sources from Kamser and Jhelum decreased marginally (e.g., 8%).

The SEM values achieved on Mach Hills aggregates have demonstrated the efficacy of the ASTM C1260, in contrast to the ASTM C227, in enhancing the identifier of possible ASR in low reactive aggregates.

The expansion of mortar bars including the Mach Mountains aggregate was the greatest on average. At the end of six months, specimens including the Mach, Tuguwali, and Sheikh Mountains aggregates displayed expansion in the range of 0.05-0.07 percent.

The results corroborated the petrographic test. According to ASTM C33, aggregates are alkali-silica reactive if the mortar bar expands by more than 0.10% after six months when tested according to ASTM C227.

None of the aggregates examined in this study expanded by more than 0.07%. After a six-month exposure time, no discomfort was seen on mortar bar surfaces. Nevertheless, ASTM C227 is not utilized to determine whether or not aggregate sources are acceptable. Typically, the longer-term ASTM C1293 is used for this purpose.

After 14 and 28 days, the specimens made from the Mach, Tuguwali, and Sheikh Mountains' aggregate origins, all of which originate in the Sargodha region, demonstrated expansion values of >0.10 and 0.20 percent, respectively. As a result, such aggregates can be classified as alkali-silica reactive according to ASTM C1260 and ASTM C227 testing determined that these aggregates were not reactive. ASTM C1260 has always been deemed more useful for assessing slow-reacting minerals.

Mortar expansion tests revealed that aggregates from the Jhelum and Kamser rivers are non-reactive when tested using ASTM C227 and C1260 tests. However, according to ASTM C227 and ASTM C1260, mortar expansion values for this aggregate source were 0.04 and 0.085 percent, respectively. This can be explained by the so-called pessimum phenomenon, in which it is claimed that the Jhelum River aggregate's 77 percent reactive mineral concentration exceeds the pessimum value, resulting in minimal expansion. This, however, should be examined further using ASTM C1293.

3.14 Comparison Between ASTM C1567 and ASTM C227 to Reduce ASR

Ashish K. Saha [31] explained in his study the primary objective was to analyze the two separates commonly used test methods for identifying the ASR of ferronickel slag fine aggregates, such as ASTM C1567 and ASTM C227. The ASR mitigation was measured by applying additional cementitious materials, including fly ash. During the experimental study, visual examination, an expansion of the mortar bar, and tensile strength testing were tested, the test outcomes suggest that because of substantial alkali leaching in the experiment.

The mortar bar system failed to classify the ASR. On the other hand, ASR was successfully detected by the accelerated mortar bar method and was successfully detected the safe dose of fly ash to minimize this harmful expansion. During AMBT, the ASR reduction was tested visually, by mortar bar extension, and by tensile strength calculations, using 30% fly ash to reduce aggregate ASR.

Compared with ASTM C227 for ASR measurement of reactive aggregates and evaluation of ASR reduction steps, ASTM C1567 was found to be more accurate.

As can be seen, the OPC100 sample expanded significantly between 3 and 16 days and surpassed the standard's permitted limit. The expansion was 0.62 percent after 16 days of exposure, which is more than six times the permissible limit.

Additionally, FA10 expanded gradually from 7 to 16 days. After the test, the expansion was 0.33 percent, significantly greater than the permitted limit, even though fly ash application reduced the expansion by 46 percent as compared to the control sample. Additionally, FA20 samples expanded gradually over the 16-day test period, reaching a final expansion of 0.13 percent, despite the addition of 20% fly ash, which reduced the expansion by 79 percent compared to the control sample. Finally, FA30 samples expanded steadily during the test period, reaching a maximum of 0.05 percent after 16 days, well within the permitted limit of 0.1 percent. As a result, the application of 30% fly ash was determined to be a viable ASR mitigation strategy under ASTM C1567. By alkali binding, portlandite consumption, pozzolanic reaction, and minimizing interconnected voids, 30% fly ash minimizes the ASR in AMBT.

On the other side, ASTM C227 indicates that OPC100 expansion grew progressively from 14 to 90 days and then stabilized at 0.06 percent. After 180 days of testing, the expansion was 0.08 percent, comfortably below the permitted range. Increasing alkali leakage from the test specimens reduced the alkali content in the pore solution, hence preventing the important first step of ASR, aggregate dissolving caused by a high alkali content in the pore solution. Additionally, FA10 samples expanded steadily throughout 60 days, reaching a maximum of 0.058 percent at the end of the test. Similarly, FA20 and FA30 samples expanded steadily and ended up at 0.031 and 0.024 percent, respectively, indicating that these samples did not suffer from an alkali-silica

reaction. Significant alkali leaching occurred during the test, limiting the increase of alkali silicate gel to within the regulatory limit.

3.15 ASR of Alkali-Activated Concrete Determined by ASTM C1293 and 1567

In this study by Zihui Li et al. [32], an experimental study of ASR of alkali-activated concrete is discussed. The authors applied OPC, AAF, AAS concrete containing reactive and non-reactive aggregates to conduct rapid and long-term ASR test protocols (ASTM C1567 and C1293) to resolve this controversy.

The present article summarizes an experimental investigation into the alkali-silica reactivity of AAF and AAS concrete. The authors aim to investigate the appropriateness of existing long-term and rapid standardized ASR test methods for predicting AAC and decide if AAF and AAS concrete are responsive to ASR when produced with reactive aggregates.

Expansions greater than 1000 for the accelerated test technique (ASTM C1567) and 400 for the long-term test technique (ASTM C1293) indicate the possibility of harmful ASR.

As expected, independent of binder type (AAS, AAF, or OPC), expansion was many times greater for reactive aggregate-containing concretes than for non-reactive aggregate-containing concretes. This difference became obvious after approximately 28 days of exposure; the expansion of AAF concrete with reactive aggregate did not exceed the 400 limits, although being many times that of non-reactive aggregate.

After approximately 100 days, the mass change in OPC concrete was significantly greater with reactive aggregate, although only by a modest margin (10 percent). In comparison, the mass shift in AAC with reactive aggregate was 50-100% greater than with non-reactive aggregate. Furthermore, with AAC containing reactive aggregate, the trend in mass change over time was considerably different. Rather than plateauing after 180 days, the mass increase in AAC with reactive aggregate proceeded to accelerate, reaching or exceeding 1% after a year.

AAS increased the most in the presence of reactive aggregates, whereas AAF grew the least. Given that all specimens were constructed using inert aggregates and that the expansions are all rather minor, there is little reason to infer ASR. Additionally, there is little indication that the activator concentration or solution-binder ratio has a significant effect on the resultant expansion. The most striking observation is that the short-term expansion measurements are markedly different from the long-term expansion measurements. For example, while the long-term growth of mixture F3 was negligible, the short-term expansion was 50% greater than the test threshold. Likewise, with AAF mixture F1.

3.16 Comparing the Ability of Admixtures to Mitigate ASR Using a Variety of Accelerated Methods

This analysis made by Halit Yazici et al. [33] compares AMBT (ASTM C1260 and C1567) and RILEM AAR-4 methods. In AMBT and RILEM AAR-4 processes, 96 mixes with 2 reactive aggregates were formed for this purpose. It was also calculated the effect of steam curing.

ASR mechanisms for reducing SCM checked in AMBT, and AAR-4 research tests are substantially different. The expansion potential of cement and aggregate is proportional to the SCM substitution ratio. The expansion patterns of the humid cured samples were identical to those of the Steam treated in both rapid testing methods except for several lithium salt-containing mixtures.

In the event of blends containing fly ash and silica fume, there were strong ties between AMBT and AAR-4 test methods. On the other hand, there was no meaningful association between these accelerated approaches in assessing all SCM-containing mixtures.

The correlations between the AMBT 14-day expansion values and the AAR-4 8-week, 13-week, and 20-week expansion values were determined in this study. There are strong correlations between the AMBT and AAR-4 test techniques for mixes including FA and SF. Mixes containing FA and SF have the highest coefficients of

determination (R2). However, when all SCM-containing mixes are evaluated, it is clear that there is little correlation between the two test methods.

While the expansion values of the mortar exceed the 14-day limit of 0.1 percent AMBT (ASTM C1567 and ASTM C1778), the expansion values of the concrete are within the AAR-4 standards (0.02 percent, 0.03 percent, and 0.04 percent). The AMBT method's apparent severity (80 °C 1 N NaOH solution) is shown. On the other hand, the greater temperature level (60 °C) in AAR-4 compared to RILEM AAR-3 and ASTM C1293 (38 °C or 40 °C) results in increased alkali leaching, reducing the eventual prism expansion.

Visual signs of severe alkali leaching were not noticed in this study's concrete specimens (AAR-4). Additionally, more ettringite becomes soluble in AAR-4 than in RILEM AAR-3 or ASTM C1293. This results in a decrease in the number of hydroxyl ions in the pore solution of concrete prisms (pH lowers). The percentage of mixes that are reactive (possibly harmful expansion) in the AMBT but non-reactive in the AAR-4 test technique during the eighth week (expansion limit: 0.02 percent) is 41.7 percent. However, in the 13th and 20th weeks, this ratio reduced to 37.5 percent and 31.2 percent, respectively. If these evaluations were conducted by ASTM C1260-14, which classifies mortar bars that have expanded by more than 0.20 percent as having experienced deleterious expansion, the above-mentioned ratios would be 22.9 percent (8 weeks), 18.7 percent (13 weeks), and 12.5 percent (20 weeks), respectively. However, as previously stated, the review was conducted by the revised standard guide (ASTM C1778). The AMBT approach appears to be more compatible with the settings recommended by the "PARTNER" Project for the AAR-4 test technique.

3.17 Comparative Study of Short- and Long-Term ASR Tests Methods on Cementitious Materials

This research by Sivrikaya, Demir, and Sevim [34], investigated by short and long-term methods of ASR the impact of 0, 5, 10, 15, and 20 %wt. cement replacement. The variations between the ASTM C1260 and the ASTM C227 test methods were contrasted in this study. Samples were produced for ASTM C1260 in Sodium hydroxide solution within 14 days and produced in the standard Water Solution for

ASTM C227 waited for 360 days. Therefore, the mortar bars were graded as innocuous for ASR in these test methods with a 20 percent of fly ash ratio additive. The study found that samples with the same preparation phases can yield different results depending on the quantity of material in the contents; the expansion ratios were different in the long term due to ASTM C1260 and ASTM C227.

Per the ASTM C1260 test method, the reference specimen expanded by greater than 0.2 percent, which is the limit value for deleterious ASR, however, based on the ASTM C227 test method, the reference specimen remained in the dangerous region by expanding by greater than 0.1 percent. When both experimental procedures were examined, it was determined that the reference sample included hazardous ASR. While mortar bars with a 5% or 10% additive ratio are categorized as having an acceptable ASR by ASTM C1260, they are classed as having a detrimental ASR by ASTM C227. Mortar bars containing 15% fly ash were classed as accepted ASR as shown by ASTM C1260, but as non-deleterious ASR according to the ASTM C227 test method. Mortar bars containing 20% fly ash were classified as safe for ASR in both test methods. Both test techniques seem to use the same specimen preparation techniques. However, it is the variation in different curing that distinguishes the two test techniques. It was discovered in this study that long-term and short-term test procedures produce nearly identical results. It is recognized that the ASTM C1260 short-term test method does not produce a safe result over an extended period. It has been demonstrated that employing long-term test methods to determine the influence of ASR on cement at later ages produces the safest results.

3.18 The Distinction Between Field and Laboratory Test Results for ASR

Jussara Tanesi et al. conducted this research [35]. Two new research methodologies have been proposed, the MCPT and the CCT, but the findings from outdoor blocks still need to be benchmarked. This paper compares the outcomes of the MCPT, CCT, CPT, and revealed blocks, and examines their capability to determine their anticipated behavior in ASR services correctly. The findings are presented here for the containing

four reactive aggregates: Spratt, Placitas (coarse aggregates), Wright and Jobe (fine aggregates), and SCMs (fly ashes classes F, or C, slag cement, and/or silica fume). The MCPT could accurately measure the efficacy of the ASR preventive steps with the long-term findings from the blocks subjected to these mixtures.

Most blocks were between thirteen and fifteen years old, except two, which were five. The purpose of this investigation was to determine if these test methods are capable of accurately assessing the danger of ASR-containing mixes generating harmful expansions.

This article summarizes data from a study that compared the findings of various ASR tests (ASTM C1293, AASHTO T 380, and CCT at 38 and 50 degrees Celsius) with the expansions of subjected blocks for the same combinations. The combinations included one of the reactive aggregates: Spratt, Wright, or Jobe, as well as SCMs (fly ash, slag, or silica fume) at varying amounts of cement replacement or lithium nitrate.

For MCPT, it was simple to do, quick, and reliable, and had a strong correlation with the blocks' efficiency. MCPT at 56 days examined the performance of a preventive strategy in comparison to the performance of the same mixture in the blocks for the majority of mixtures assessed. Two combinations had ambiguous effectiveness of the measures after 56 days, but when the findings at 84 days were considered, these measures were classed as "inefficient." It provided a false negative result (equal to 6%) for one combination and two potentially false positives for another (equivalent to 12 percent). It is unknown whether they are genuine false positives since the corresponding blocks are still extremely young and may develop ASR in the future. It could not compare favorably to C1293, as nine out of seventeen mixes that passed C1293 failed the MCPT.

For CCT, there was theoretical promise because any leached alkali was predicted to remain in direct contact with the specimen in the mold. It was vulnerable to leakages, which resulted in specimen drying and the loss of alkalis leached from the cylinder, thereby negating the test's primary advantage over C1293. Both drying and alkali loss could have influenced the expansion results, increasing the variability of the data, particularly when compared to the MCPT values. CCT at 50 °C produced 54% false

negatives and 64% false negatives at 38 °C, compared to C1293, which produced 53% false negatives. Additionally, it required an extended testing period and was incapable of accurately forecasting the future outcomes of the investigated combinations in the field.

3.19 Accelerated Laboratory and Long-Term Studies Monitoring to Evaluate ASR

This research carried out by Shuqing Yang, Jian-Xin Lu, and Chi Sun Poon [36], aimed to validate the advantage of the dry-mixed approach using long-term (15-year) field surveillance since a study on the ASR behavior of dry-mixed mortars was not previously announced. The finding showed how the developments of glass aggregate ASR gel were compatible with the findings of long-term field monitoring in dry-mixed Mortar studies of lab tests (ASTM C1260 and C227).

After 6 months of the ASR procedure, the ASR gel was first observed in the macro-pores of the dry-mingled Mortar (ASR external glass gel) and not due to an expansion only in the outdoor surface of the glass aggregates, as stated in ASTM C227 (laboratory test). The ASR gel was later located within the glass aggregates' pre-present internal fractures. No internal-glass ASR gel was identified in the 15-year-old blocks, indicating the ASR rate in the field is substantially slower. The research findings also stated that the additional utilization of glass powders as additional cement content was effective in regulating the formation in dry-mixed mortuaries of the deleterious internal glass ASR gel, which could further increase the use of concrete block wastes. The lower ASR response average in the field, with an average of RH: 80% and the temperature ranged from 22 °C to 27 °C, was detected only by the outside-glass ASR gel and no ASR glass gel was detected. The findings showed that dry-mixed blocks incorporating 50% glass would be subject to a low risk of ASR damage.

As predicted, the mortar bars made entirely of glass aggregate in place of river sand expanded the most in both experiments, particularly the wet-mixed mortars. The

ASTM C1260 test requires that the expansions continue after the 14 days of the test. In the first six months of ASTM C227 testing, the expansion rates of all three series of combinations were fairly low. However, after approximately six months, the expansion rates of all three series of combinations dramatically rose. The distinction between ASTM C1260 and C227 was that the latter test documented a time lag in ASR expansion. The increased temperature and concentration of accessible alkalis in the test account for the ASTM C1260 test's accelerated ASR expansion.

When comparing 100 percent GA-WMI to 100 percent GA-WMII, both experiments revealed that the expansion values of moist mortars increased as the w/c ratio decreased. It was previously established that a higher w/c ratio results in increased porosity, which may partially alleviate the ASR expansion pressure. For all sets of testing, the expansion rates of dry-mixed mortars (100 percent GA-DM) made with the same w/c ratio (100 percent GA-WMII) were much less. The coarse permeability of the specimen was 3.7 percent, whereas the moist specimen had a coarse porosity of 2.9 percent. When the glass aggregates were used to replace 50% of the river sand in the ASTM C1260 test, the expansion rates of the moist mortars (50 percent GA-WMI and 50 percent GAWMII) still exceeded the 0.1 percent limit after 14 days. Although the expansion values of the two series of moist mortars (50 percent GA-WMI and 50 percent GA-WMII) were less than the ASTM C227 limit of 0.1 percent after 12 months, the expansion curves continued to move upward. In comparison, the expansion values of dry-mixed mortars (100 percent GA-DM) were low and appeared to remain constant after 14 days of ASTM C1260 testing and 12 months of ASTM C227 observation.

CHAPTER 4

CONCLUSION AND RECOMMENDATION

Alkali-silica Reaction (ASR) is the deleterious swelling reaction between the highly alkaline cement pastes and reactive (non-crystalline) silica contained in many typical aggregates given ample moisture. ASR is more generally known as "concrete cancer", thus, find ways to detect this reaction is needed.

It should be noted that this study does not depend on new results produced by the researcher, but on the results of previous researches and studies carried out by other researchers therefore this chapter will present a conclusion for each research or study mentioned in Chapter 3. Noting that the Short-Term methods mean methods that have a duration of not more than 6 months, and the Long-Term methods mean methods that have a duration of more than 6 months.

4.1 Conclusion

1. In “Predictability of Aggregates Improved by ASR Study” [18], by applying ASTM C289 and C295 on concrete, there is a lack of correlation between chemical and mortar-bar tests is generally a result of the mortar bars' unpredictable expansion. Due to the fact, that tends to impact the reactivity of alkali-silica, adding them to concrete can be a useful way to make them functional.
2. It is noticed in “Comparative Study of Field and Lab Results on Concrete on ASR” [19], that the presence of opal shale in the fine aggregate fails in all concrete. While the C1260 in these pavements suggested the likelihood of excessive expansion, laboratory samples of the C1293 demonstrated identical symptoms to field concrete. Additionally, it was noted that when crushed quartzite was used, mortar samples for the C1260 had contradictory results. On the contrary, the C1293 test unequivocally established that the quartzite posed a risk of detrimental expansion.
3. In a “Comparative Study between RTA T363 and ASTM C1260 Methods to detect reactive aggregates” [20], it is found that the higher expansion in ASTM C1260 is owing to the method's high w/c ratio of 0.47, compared to 0.40-0.42 in the RTA T363

method, which results in improved porosity and easier access to the aggregate for the NaOH processing solution. Additionally, the results of this investigation indicate that both processes exhibited cracking in mortar bars composed of Japanese aggregate and 25% fly ash, this confirms the finding of RTA T363 that a 25% fly ash replacement rate was insufficient to prevent AAR expansion.

4. For the study of "Checking of Recycled Concrete Using Accelerated ASR Test" [21], after 21 days, the holes in the samples expanded around 65 percent more than the solid samples and 33 percent more than the cut samples according to ASTM C1260. The solid sealed samples displayed the least mass gain for a given expansion, which contrasted sharply with the ASTM C1293 test findings. When microwave cubes are compared to sealed cubes in ASTM C1293, the microwave has a minor effect on expansion.

5. The study of "Predicting ASR Using ASTM C1293, C1260, and Their Updates" [22] compared 14-day expansions achieved under ASTM C1260 to 52-week expansions obtained under ASTM C1293. For innocuous aggregates, 14-day expansions of less than 0.10 percent were substantially correlated with 52-week expansions of less than 0.04 percent. Notably, ASTM C1260 should not be used in isolation but should be complemented with ASTM C1293, while ASTM C1293 may be used independently to forecast the AAR.

6. For Suggested Autoclaving in Glass Aggregate Bound Composites for ASR Screening [23], there was a link between the findings of the autoclave test and the ASTM C1260 test only when combinations resisted the touch of a sodium hydroxide solution. Concerning glass aggregate formulations, the ASTM C1260 test does not seem to be all that exact. These findings show that autoclave testing is beneficial since it enables concrete with standard components such as water, cement, sand, and gravel, as well as additives, pozzolans, or irregular aggregates to be examined.

7. In the "Test of ASR Using a Modified ASTM C1260" study [24], Although the expansion of fly ash bars is often less, a 20% substitution of fly ash may not be optimal for w/c = 0.47 to get a lower expansion. In contrast to cement-based mortar bars that undergo the ASTM C1260 method of wet-curing for 24 hours, the fly ash-based mortar

bars demonstrate more expansion than that type of mortar bar that was only treated with the ASTM C1260 method for 28 days.

8. "ASR in Mortars Produced from Aggregates of Various Levels of Crystallinity" study [25] showed that the presence of intermediate and poorly crystalline aggregates, the effect of crystalline material in precise proportions in concrete and mortar may prevail. When the maximum impact is considered for flint and diatomite, the projected expansion of the mortar bars closely matches the crystallinity of the various silica aggregates. While no significant expansion was seen in the case of the quartz aggregate.

9. For “A Critical Evaluation for ASR Performance in Concrete” study [26], the research showed that no single method is optimal for determining the alkali-silica reactivity of aggregate, that the alkali content of cement does not affect mortar bar expansion, and that restricting cement alkalis to less than 0.6 percent Na_2O_{eq} does not prevent ASR from falling below the prescribed expansion levels. However, including a suitable amount of pozzolans in the concrete mix, such as fly ash, improves the concrete's characteristics and mitigates the harm caused by ASR except for the rhyolite aggregate group. In comparison to other test methods, the concrete prism test may provide the most accurate estimate of ASR due to the specimens' increased exposure to actual field conditions.

10. “Assessing ASR of Aggregate Using an Accelerated Autoclave Test” study [27] established that the aggregate expansion in ASTM C1260 is astronomically high when compared to ASTM C1293 and its well-documented field performance. Additionally, autoclaved CPT appears to exhibit some irreducible expansivity, even when non-reactive aggregates are confirmed.

11. According to the “New Test for AAR in Iceland” study [28], it is considered insufficient to add silica fume to the mixture in the laboratory because the silica fume is unlikely to be distributed evenly. Also, ASTM C227, RILEM AAR-3, and RILEM AAR-4 tests illustrate that the mixture with the highest alkali cement content and no added pozzolanas expand the most.

Additionally, the RILEM AAR-2 test indicates that there is no discernible effect of reduced expansion with pozzolanas or low alkali concentrations in the cement types tested.

12. "ASR Kinetic Approach: Comparative Study of Lab and Field Results" study [29] shows that due to the harsh conditions in which AMBT operates, it is excessively reactive, and it grossly underestimates the reactivity of certain aggregation types. CPT is a time-consuming procedure that correlates more favorably with field performance than AMBT.

CPT or ACPT can be used to determine kinetic parameters, and the same theory and equation hold for field measurements. On the other hand, ACPT permits shorter test durations.

13. "Role of The Test Method in The Detection of Alkali-Silica Reactivity of Concrete Aggregates" study [30] stated that after 14 and 28 days, the specimens with expansion values greater than 0.10 percent and 0.20 percent, respectively. As a result, these aggregates can be defined as alkali-silica reactive under ASTM C1260, ASTM C227 testing determined that they were not reactive. As a result, ASTM C1260 has historically been considered more useful for evaluating slow-reacting minerals. Mortar expansion tests revealed aggregates with expansion values of 0.04 and 0.085 percent are non-reactive when subjected to ASTM C227 and C1260 tests, respectively. However, ASTM C1293 should be used to conduct additional testing.

14. According to the "Comparison Between ASTM C1567 and ASTM C227 to Reduce ASR" study [31], after visual inspection, mortar bar extension, and tensile strength calculations, it was determined that the application of 30% fly ash was a feasible ASR mitigation strategy under ASTM C1567. Through alkali binding, portlandite consumption, pozzolanic reaction, and void minimization, 30% fly ash reduces the ASR in AMBT. ASTM C1567 was found to be more reliable than ASTM C227 for determining the ASR of reactive aggregates and evaluating ASR reduction steps.

15. "ASR of Alkali-Activated Concrete Determined by ASTM C1293 and C1567" study [32] indicates that the expansion was significantly greater for reactive aggregate-

containing concretes than for non-reactive aggregate-containing concretes, regardless of binder type (AAS, AAF, or OPC). Expansions greater than 1000 με in the accelerated test (ASTM C1567) and 400 με in the long-term test (ASTM C1293) indicate the possibility of harmful ASR.

16. The study "Comparing the Ability of Admixtures to Mitigate ASR Using a Variety of Accelerated Methods" [33] showed that mixtures containing FA and SF, have a significant correlation between the AMBT and AAR-4 test methods.

The higher temperature level (60 °C) in AAR-4 compared to RILEM AAR-3 and ASTM C1293 (38 °C or 40 °C) results in increased alkali leaching, thereby reducing prism expansion. The AMBT approach appears to be more compatible with the AAR-4 test technique settings recommended by the "PARTNER" Project.

17. By "Comparative Study of Short- and Long-Term ASR Tests Methods on Cementitious Materials" [34] Mortar bars with a fly ash ratio of 5% or 10% are classified as acceptable ASR by ASTM C1260; however, they are classified as detrimental ASR by ASTM C227. Mortar bars containing 15% fly ash were classified as accepted ASR by ASTM C1260, but as non-deleterious ASR by ASTM C227. Both test methods classified mortar bars containing 20% fly ash as safe for ASR.

From the foregoing, it appears that both test procedures to be identical in terms of specimen preparation but the variation in curing methods is what recognizes the two test techniques.

18. From "The Distinction Between Field and Laboratory Test Results for ASR" [35], the study found that MCPT was straightforward, quick, and reliable, and had a strong correlation with the blocks' efficiency. At 56 days, it compared the performance of a preventive strategy to the performance of the same mixture in the blocks for the majority of mixtures assessed. It could not stand up to C1293, as nine of seventeen mixes that passed C1293 failed the MCPT.

For CCT had theoretical promise because any leachable alkali was expected to stay in direct contact with the specimen in the mold; however, it was susceptible to leakages, which resulted in specimen drying and the loss of alkalis leached from the cylinder, negating the test's primary advantage over C1293. Additionally, it necessitated a

lengthy testing period and was incapable of forecasting the future outcomes of the combinations investigated in the field.

19. It is concluded from the "Accelerated Laboratory and Long-Term Studies Monitoring to Evaluate ASR" study [36], the ASTM C1260 test required that the expansions must continue for a further 14 days. The expansion rates of all three series of combinations were relatively low during the first six months of ASTM C227 testing but dramatically increased after approximately six months. The difference between ASTM C1260 and C227 was that the latter test demonstrated a lag in ASR expansion. The ASTM C1260 test's accelerated ASR expansion is due to the increased temperature and concentration of accessible alkalis.

4.2 Recommendation

- This study gives preferences regarding how to choose the best experiment to perform alkali-silica screening.
- For Short-Term test methods, the preferable method to use is ASTM C1260, but it is recommended to work on developing the SCPT method and making it suitable for all test conditions and accepted because the researcher Alkan Hafci has made great efforts to link the characteristics of the test in the short and long term.
- For long-term testing methods preferred to use ASTM C1293 because it is considered one of the latest long-term methods and approved by ASTM.

REFERENCES

[1] V. S. Ramachandran, Concrete Admixtures Handbook Properties, Science, and Technology 2nd Edition, Noyes publications, USA, 1995.

[2] Fatih BEKTAŞ, M.Sc. Thesis "Preventive Measures Against Alkali-Silica Reaction", Turkey, 2002.

[3] Alkan HAFÇI, Ph.D. Thesis "development of a new short-term concrete prism test method (SCPT) to improve predictability for potential alkali reactivity of aggregates", Turkey, 2019.

[4] American Society for Testing and Materials, Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method), ASTM C227-10, USA, 2010.

[5] American Society for Testing and Materials, Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method), ASTM C289-07, USA, 2007.

[6] Enamur Latifee, Miniature Concrete Prism Test - a New Test Method for Evaluating the ASR Potential of Aggregates, the Effectiveness of ASR Mitigation and the Job Mixture, Clemson University, USA, 2013.

[7] American Society for Testing and Materials, Standard Guide for Petrographic Examination of Aggregates for Concrete, ASTM C295 / C295M-12, USA,2012.

[8] American Society for Testing and Materials, Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction, ASTM C1293-20, USA, 2020.

[9] David Stark, Sidney Diamond, and Micheline Moranville-Regourd, Alkali-Silica Reactivity: An Overview of Research, Strategic Highway Research Program, SHRP-C-342, USA, 1993.

[10] B. Foumier & M. A. Berube, Recent Applications of a Modified Gel Pat Test to Determine the Potential Alkali-Silica Reactivity of Carbonate Aggregates, Cement & Concrete Composites Vol. 15, pp. 49-73, Canada, 1993.

[11] American Society for Testing and Materials, Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks as Concrete Aggregates (Rock-Cylinder Method), ASTM C586-11, USA, 2011.

[12] S. Chatterji, "An Accelerated Method for The Detection of Alkali- Aggregate Reactivities of Aggregates", Cement and Concrete Research Vol. 8, pp. 647-650, USA, 1978.

[13] Japanese Industrial Standard JIS, Alkali silica reactivity test method for aggregates (Mortar bar method), A1146:2017, Japan, 2017.

[14] Tang Ming-Shu, HanSu-fen, and Zhen Shi-Hua, A Rapid Method for Identification of Alkali Reactivity of Aggregate, Cement and Concrete Research Vol. 13, pp. 417-422, USA, 1983.

[15] American Society for Testing and Materials, Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method), ASTM C1260-14, USA, 2014.

[16] Kumar C. Natesaiyer and Kenneth C. Hover, Further Study of An In-Situ Identification Method for Alkali-Silica Reaction Products in Concrete, Cement and Concrete Research Vol. 19, pp. 770-778, USA, 1989.

[17] S. Chatterji, A Simple Chemical Test Method for The Detection of Alkali-Silica Reactivity of Aggregates, Cement and Concrete Research Vol. 18, pp. 654-656, USA, 1988.

[18] Heck, W. J., "Study of Alkali-Silica Reactivity Tests to Improve Correlation and Predictability for Aggregates," Cement, Concrete, and Aggregates, CCAGDP, Vol.5, No.1, Summer 1983, pp.47-53.

[19] Whiting, N. M., "Comparison of Field Observations with Laboratory Test Results on Concretes Undergoing Alkali-Silica Reaction," Cement, Concrete, and Aggregates, CCAGDP, Vol.21, No.2, pp. 142–148, Dec. 1999.

[20] Ahmad Shayan and Howard Morris, A comparison of RTA T363 and ASTM C1260 accelerated mortar bar test methods for detecting reactive aggregates, Cement and Concrete Research, Vol.31, pp. 655-663, 2001.

[21] D.L. Gress, R.L. Kozikowski, and T.T. Eighmy, Accelerated ASR testing of recycled concrete, Waste Management Series, pp. 221-233, December 2000.

[22] Wissam E. Touma, David W. Fowler, Ramon L. Carrasquillo, Kevin J. Folliard, and Norman R. Nelson, Characterizing Alkali-Silica Reactivity of Aggregates Using ASTM C 1293, ASTM C 1260, and Their Modifications, Transportation Research Record 1757 Paper No. 01-3019, pp. 157-165, 2001.

[23] S. Kozlova, K. Millrath, C. Meyer, S. Shimanovich, A Suggested Screening Test for ASR in Cement-Bound Composites Containing Glass Aggregate Based On Autoclaving, Cement & Concrete Composites Vol.26, pp. 827–835, 2004.

[24] Chang-Seon Shon, Dan G. Zollinger, Shondeep L. Sarkar, "Evaluation of modified ASTM C 1260 accelerated mortar bar test for alkali-silica reactivity", Cement and Concrete Research Vol.32, pp. 1981–1987, 2002.

[25] Ana Mladenovič, Sašo Šturm, Breda Mirtič, Jerneja Strupi Šuput, "Alkali-Silica Reaction in Mortars Made from Aggregates Having Different Degrees of Crystallinity", Ceramics – Silikáty Vol. 53 (1) pp. 31-41, 2009.

[26] Mohammad Shahidul Islam, and Sazeda Akhtar, A Critical Assessment to the Performance of Alkali-Silica Reaction (ASR) in Concrete, Canadian Chemical Transactions, Vol. 1, Issue 4, pp. 253-266, 2013.

[27] Eric R. Giannini and Kevin J. Folliard, A Rapid Test to Determine Alkali-Silica Reactivity of Aggregates Using Autoclaved Concrete Prisms, PCA R&D Serial No. 3235, 2013.

[28] Sóley Unnur Einarsdóttir, Børge Johannes Wigum, Alkali Aggregate Reaction in Iceland - New Test Methods, Mannvit Engineering, Grensásvegur 1, IS-108 REYKJAVIK, Iceland, 2014.

[29] N. Gowripalan and Vute Sirivivatnanon, Kinetic based approach for Alkali-Silica Reaction-Comparison of laboratory and field tests, University of Technology Sydney, Australia, 2017.

[30] Muhammad Junaid Munir, Safeer Abbas, Asad Ullah Qazi, Moncef L. Nehdi, Syed Minhaj Saleem Kazmi, Role of the test method in the detection of alkali-silica reactivity of concrete aggregates, ICE Publishing, Paper 1600058, 2017.

[31] Ashish K. Saha, A comparative study between ASTM C1567 and ASTM C227 to mitigate alkali-silica reaction, International Federation for Structural Concrete, Vol.20, pp. 420–427, 2019.

[32] Zihui Li, Robert J. Thomas, Sulapha Peethamparan, Alkali-silica reactivity of alkali-activated concrete subjected to ASTM C 1293 and 1567 alkali-silica reactivity tests, Cement and Concrete Research, Vol.123, No.105796, 2019.

[33] Halit Yazıcı, Ahsanollah Beglarigale, Kamile Tosun Felekoglu, Selçuk Türkel, Comparing the alkali-silica reaction mitigation potential of admixtures by using different accelerated test methods, Construction and Building Materials Vol.197, pp. 597-614, 2019.

[34] Burak Sivrikaya, İlhami Demir, Özer Sevim, Comparison of short- and long-term ASR test methods on cementitious composites, Challenge Journal of Structural Mechanics, Vil.6, pp. 68-72, 2020.

[35] Jussara Tanesi, Thano Drimalas, Krishna Siva Teja Chopperla, Mengesha Beyene, Jason H. Ideker, Haejin Kim, Luca Montanari, and Ahmad Ardani, "Divergence between Performance in the Field and Laboratory Test Results for Alkali-Silica Reaction", Transportation Research Record, 2020.

[36] Shuqing Yang, Jian-Xin Lu, Chi Sun Poon, Recycling of waste glass in dry-mixed concrete blocks: Evaluation of alkali-silica reaction (ASR) by accelerated laboratory tests and long-term field monitoring, Construction and Building Materials, Vol.262, p.120865, 2020.

JULY 2021

ANKARA

Department of Civil Engineering **Saifuldeen Sufyan Ahmed AL-INIZI**